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THESIS

A SYSTEMS ENGINEERING DESIGN ANALYSIS OF A U.S. ARMY SECURE STORAGE SYSTEM

by

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March 2002

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13. ABSTRACT ***(maximum 200 words)***

As the Army develops and fields new or improved tactical equipment for the soldier, the challenge of providing for its security, unit-level maintenance, availability, and accountability will exceed the capacity of present systems. This new or improved tactical equipment will include a number of high-cost, technically advanced items that will present storage and other logistical challenges. In garrison, the fixed facilities at unit level are inadequate for the projected need (both quantitatively and qualitatively). Finally, there are no current systems specifically designed to provide security, protected storage, availability, and accountability of sensitive and high-value non-sensitive items during training or operational deployments

This thesis uses a tailored application of the systems engineering process to develop a design for a U.S. Army secure storage system. This study investigates the user's requirements for such a system, as well as requirements and constraints derived from security regulations, military and commercial intermodal transportation methods, and current Army facilities and force structure. It then examines existing Government and commercial equipment to assess their suitability for satisfying secure storage and transportation requirements. Ultimately, this system engineering analysis produces a physical architecture of a mobile secure storage system, as well as selected items of the system architecture.

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A SYSTEMS ENGINEERING DESIGN ANALYSIS OF A U.S. ARMY SECURE STORAGE SYSTEM

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ABSTRACT

As the Army develops and fields new or improved tactical equipment for the soldier, the challenge of providing for its security, unit-level maintenance, availability, and accountability will exceed the capacity of present systems. This new or improved tactical equipment will include a number of high-cost, technically advanced items that will present storage and other logistical challenges. In garrison, the fixed facilities at unit level are inadequate for the projected need (both quantitatively and qualitatively). Finally, there are no current systems specifically designed to provide security, protected storage, availability, and accountability of sensitive and high-value non-sensitive items during training or operational deployments

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I. INTRODUCTION

This chapter provides general information, research questions, discussion of the issues, scope, methodology, benefits of the study, and organization of the study.

A. GENERAL INFORMATION

The purpose of this research is to follow a tailored systems engineering approach in order to identify an effective and suitable design for a U.S. Army secure storage system. Such a system must provide for the security, protected storage, availability, and accountability of selected items of soldier tactical equipment in garrison, during strategic deployment, and when deployed for training or operations. The acquisition of such a system is warranted due to the extensive array of weapons and high-value equipment procured by the Army in recent years, and the large number of additional systems planned for procurement in the near future. The goal is to develop a secure storage design that can satisfy a current and stated requirement of several U.S. Army weapons and equipment programs and ultimately be considered for acquisition program status by the U.S. Army.

B. RESEARCH QUESTIONS

1. Primary Question

What is a system design that can provide the Army with security, protected storage, availability, and accountability of sensitive and high-value non-sensitive items and equipment in garrison, during strategic deployment, and when deployed for training and operations?

2. Subsidiary Questions

a. What features and performance levels will the system's users require?

b. What are the major security and transportation requirements and constraints in developing a mobile secure storage system for a fixed facility, and for its deployment into an area of operations?

c. What commercial equipment and technologies are available which might be suitable for inclusion as part of a mobile secure storage system?

d. What are the benefits of such a secure system design for the Army and DoD?

C. DISCUSSION

As the Army develops and fields new or improved tactical equipment for the soldier, the challenge of providing for its security, unit-level maintenance, availability, and accountability will exceed the capacity of present systems. This new or improved tactical equipment will include a number of high-cost, technically advanced items that will present storage and other logistical challenges. In garrison, the fixed facilities at unit level are inadequate for the projected need (both quantitatively and qualitatively). The same inadequacy holds true when the anticipated items of equipment are in transit to a training area or to a mission area of operations. Finally, there are no current systems specifically designed to provide security, protected storage, availability, and accountability of sensitive and high-value non-sensitive items during training or operational deployments [Ref. 1].

D. SCOPE OF THESIS

This thesis uses a tailored application of the systems engineering process to develop a design for a U.S. Army secure storage system. This study investigates the users requirements for such a system as well as requirements and constraints derived from security regulations, military and commercial intermodal transportation methods, and current Army facilities and force structure. It then examines existing Government and commercial equipment to assess their suitability for satisfying secure storage and transportation requirements. Ultimately, this system engineering analysis will produce the physical architecture of a secure storage system, as well as selected items of the system architecture.

E. METHODOLOGY

The methodology used in this thesis research was obtained from three separate data collection efforts. First, a comprehensive literature and Internet review was conducted. This review included the examination of regulations, DoD doctrinal manuals, systems engineering guides and texts, articles, journals, periodicals, commercial sales brochures, and documentation (briefings, memorandums, and studies) from various Army and DoD organizations. Second, an interview was conducted using a synergistic "User

IPT" approach, where eleven U.S. Army officers were brought together to generate requirements based on their extensive experience as company commanders and staff officers. Third, phone interviews, personal interviews, and e-mail consultations were conducted with various Army personnel, subject matter experts, and civilian contractors to expand or verify the findings of the first two collection efforts.

F. BENEFITS OF THE STUDY

This study serves as a basis for future research and discussion on designing and developing transportable secure storage systems as well as examining storage solutions within existing facilities. Furthermore, this study hopes to bring insight into developing a standard, systemic solution that can address a multitude of future Army and DoD storage requirements. Such a systemic solution could ease the storage planning burdens of program managers, increase storage efficiency and transportability, and reduce overall system life-cycle costs.

G. ORGANIZATION

This thesis is organized in the following manner:

Chapter I provides general information, research questions, discussion of the issues, scope, methodology, benefits of the study, and organization of the study.

Chapter II presents background information on the need for expanded sensitive items and valued non-sensitive item storage and security systems in the Army. It also provides an explanation of the systems engineering process, which is used as the analysis tool for this thesis.

Chapter III is a presentation of four primary sets of data to support further analysis. The results of a "User IPT" are presented first to establish the needs and requirements of the user as it relates to secure storage. Next, information on security standards is presented to gain an understanding of regulatory requirements for secure storage and an understanding of existing secure facilities. Third, since the system must be mobile for deployment, DoD and international compatibility, transportability, and loading requirements/constraints are examined. Lastly, a market review of a variety of commercial systems is conducted to highlight existing features that may benefit the design process.

Chapter IV is a tailored systems engineering analysis. Requirements and functions are analyzed and then synthesized into what the researcher believes to be the most effective and suitable secure storage system design. This design is then analyzed to ensure it meets all required functions and satisfies the major system requirements.

Chapter V examines the primary and subsidiary research questions. Conclusions are then presented as well as recommendations for future actions.

II. BACKGROUND

This chapter presents background information on the need for expanded sensitive items and valued non-sensitive item storage and security systems in the Army. It also provides an explanation of the systems engineering process, which is used as the analysis tool for this thesis.

A. THE NEED FOR A SECURE STORAGE SYSTEM IN THE ARMY

Secure storage requirements and procedures within tactical U.S. Army units (Division level and below) have remained largely unchanged for the last century; however, these requirements are rapidly evolving and expanding as the acquisition of numerous sensitive and expensive equipment items rises dramatically. As the Army advances through its current transformation effort, which is largely focused on high technology equipment solutions, this situation is exacerbated.

The primary security concerns at the tactical level involve both sensitive and some non-sensitive items. There are two broad categories of sensitive items: arms, ammunition, and explosives and classified data and equipment. Those non-sensitive items that are easily pilfered and have a significant dollar value (known hereto as valued non-sensitive items) constitute a security concern as well. This section discusses the recent history of the Army's facilities and procedures used to secure such items. Subsequently, it outlines the growing need for additional sensitive and valued non-sensitive item secure storage systems with an increased level of capabilities.

The storage area for the all Army sensitive items and the majority of valued non-sensitive items is the unit arms room, which is generally maintained at the company level. The non-sensitive item storage area is typically either the unit supply room or a secure storage area within the supply room. Sensitive items not stored at company level are bulk ammunition and explosives, which are centralized at installation level; however, the scope of this thesis will focus only on the company level secure storage.

The company arms room is the Army's primary sensitive item security facility and is always of heavy construction: steel reinforced masonry or concrete; a heavy metal door and lock; and an internal, electronic, Intruder Detections System (IDS) to meet

specific, Army-wide, security regulations. Additionally, access to the arms room is highly restricted and entry is controlled and recorded daily as is the issue and receipt of its contents. The secure storage area for non-sensitive items, on the other hand, is not required to be a hardened structure, but rather is constructed to meet loose physical security standards in order to basically resist any unsupported method of forced entry. For example, a typical non-sensitive item storage area is fabricated from heavy wire-mesh panels bolted together and placed within a larger common area within a company's supply room or administrative area. The non-sensitive item storage area typically has various lockable containers residing within it as an additional security measure.

The Army company commander is required to store all his arms, ammunition, and classified equipment (usually unkeyed/zeroed communications security devices) in his arms room; however, based on an installation level and as well as his own personal risk assessment, the average commander will typically store much of his valued non-sensitive items in the arms room as well.

Throughout these two secure areas, with the exception of standard small arms and crew-served weapons racks in the arms room, there is no standardized container or storage system. Consequently, the arms room and non-sensitive item storage area are filled with a variety of commercial metal storage wall lockers or cabinets, or locally fabricated wooden storage compartments of virtually every size and shape imaginable. This system of storage has been adequate for many years due primarily to the relative stability of the number of personnel in company-sized units and the standard configuration of equipment issued to the average soldier. There has been little variation in the tools of the soldier's trade since before World War II; primarily consisting of his basic weapon, ammunition, load bearing equipment, and perhaps a radio. There was formerly no real extra or optional equipment to be stored for special environments or missions; consequently, the average current arms room and non-sensitive item storage area, built largely prior to the 1990s, had a place for everything and everything had its place. When the company deployed it all went on the soldier's person or in company vehicles.

Beginning in the 1970's, the Department of Defense began to apply high-technology solutions to Army weapons and communication systems. The need to develop even more capable and lightweight systems continued to grow and the commercial explosion of digital information technology in the 1980's - and especially in the 1990's - greatly enabled this development. However, with each new technological application to a legacy system, or the development of a completely new high-tech system, came new or additional requirements for storage and security.

As a result of this wave of acquisition of new and improved systems, when a U.S. Army infantry company draws its gear today in preparation for training or combat, it customizes rather than standardizes. The commander can now mix and match weapons systems, optical sights, thermal sights, laser pointing devices, communications gear, etc. as never before. This trend is rapidly continuing as the Army acquires its next generation of equipment, namely the Land Warrior system. This system is designed to be modular, and thus customizable, from the outset. It will add such features as a wearable computer and a secure communications and Global Positioning System (GPS) for each soldier that will assuredly add to future security needs.

Despite the ongoing digital revolution, the majority of secure storage inventory management is presently accomplished manually. The inventory, issue, and receipt of the contents of secure storage areas is incredibly time consuming and these exhausting processes grow ever longer as more items are added to the equation.

There are three main consequences of today's boom in sensitive item and valued non-sensitive item storage area acquisition:

First, the physical space within the average arms rooms has been exhausted. While there has been several new sensitive items introduced over the past 10 years (e.g. Global Positioning Systems, radios with integrated communications security equipment, Javelin missile launch control units, etc.) the majority of the space has been consumed by valued non-sensitive item storage area (e.g. new weapon sighting systems; night vision devices; non-secure radios; nuclear, biological and chemical detection instruments, etc.). The majority of these valued non-sensitive items have hard-sided, individual carrying/protective cases, which only exacerbate the impact on physical space within a

storage area.   The new Land Warrior System has only one sensitive item: the GPS Type III PCMCIA card, yet it has up to seven other components, which average about a cubic foot per solder, that will surely be valued non-sensitive items and will likely find their way into the arms room [Reg. 2 & 3].

Second, small arms and crew served weapon systems with technological add-ons are unable to be stored in their updated configuration. The standardized racks for individual small arms (M16/M4 series of rifles and M249 Squad Automatic Weapons) and crew served weapons (M240 Machine Gun, M2 machine gun, and M49 Automatic Grenade Launcher) cannot be adjusted; consequently, the cutting-edge sighting systems and other target acquisition aids currently applied to these weapons essentially make them wider and deeper and they are unable to fit in the existing racks in their updated configuration [Ref. 4]. This mandates that such devices be removed prior to storing the weapons, thus destroying their sighting zero – hardly a satisfactory storage solution. Furthermore, the future acquisition of the Objective Individual Combat Weapon (OICW) and the Objective Crew-served Weapon (OCSW), which will be fielded within the next 5 to 10 years, will require a different secure storage system as well.

Third, units will need some form of secure storage when deployed. Since the soldier's weapon systems can be customized there are many items in secure storage that will not initially be issued to the soldier, but which he will want to use later to accommodate changing threat scenarios and environments. This presents a problem upon deployment, as no longer can the soldier easily transport every item. Additional secure storage space will be required to transport the additional equipment as well as secure it during operational use or training. With the exception of storage within selected deploying vehicles, there is no current Army or other DoD system that can satisfy this requirement.

B. INTRODUCTION TO SYSTEMS ENGINEERING

In order to design and develop a new Army secure storage system in an organized and comprehensive fashion, a formalized management method must be utilized. To this end, this thesis will utilize systems engineering management as a guideline for the design and analysis effort.

To begin to understand systems engineering it is useful first to define exactly what a system is. The Defense Systems Management College defines a system simply as, "an integrated composite of people, products, and processed that provide a capability to satisfy a need or objective" [Ref. 5]. Therefore, systems engineering a methodology for achieving desired systems. The DSMC's definition of systems engineering is a bit more insightful:

> Systems engineering is an interdisciplinary engineering management process that evolves and verifies an integrated, life cycle balanced set of system solution that satisfy customer needs. Systems engineering is accomplished by integrating three major activities:
>
> - Development phasing - controls the design process and provides baselines that coordinate design efforts.
> - Life cycle integration – involves the customers in the design process and ensures that the system developed is viable throughout its life.
> - Systems engineering process – provides a structure for solving design problems and tracking requirements flow through the design effort.
>
> [Ref. 6].

Although Developmental phasing is important as a management tool in achieving expected levels of progress prior to continuing into a subsequent phase, and Life-cycle integration is absolutely essential to ensure the cost and performance of the system are acceptable throughout the systems lifetime, of these three activities the Systems Engineering Process will be the one this thesis is most concerned with.

The DSMC defines the Systems Engineering Process as:

> A top-down comprehensive, iterative, and recursive problem solving process, applied sequentially through all stages of development that is used to provide a structured but flexible process that transforms needs and requirements into a set of system product and process descriptions (adding value and more detail with each level of development), generate information for decision makers, and provide input for the next level of development as shown in the figure below the process includes: inputs and outputs, requirements analysis, functional analysis and allocation, requirements loop, synthesis' design loop, verification, and system analysis and control [Ref. 7].

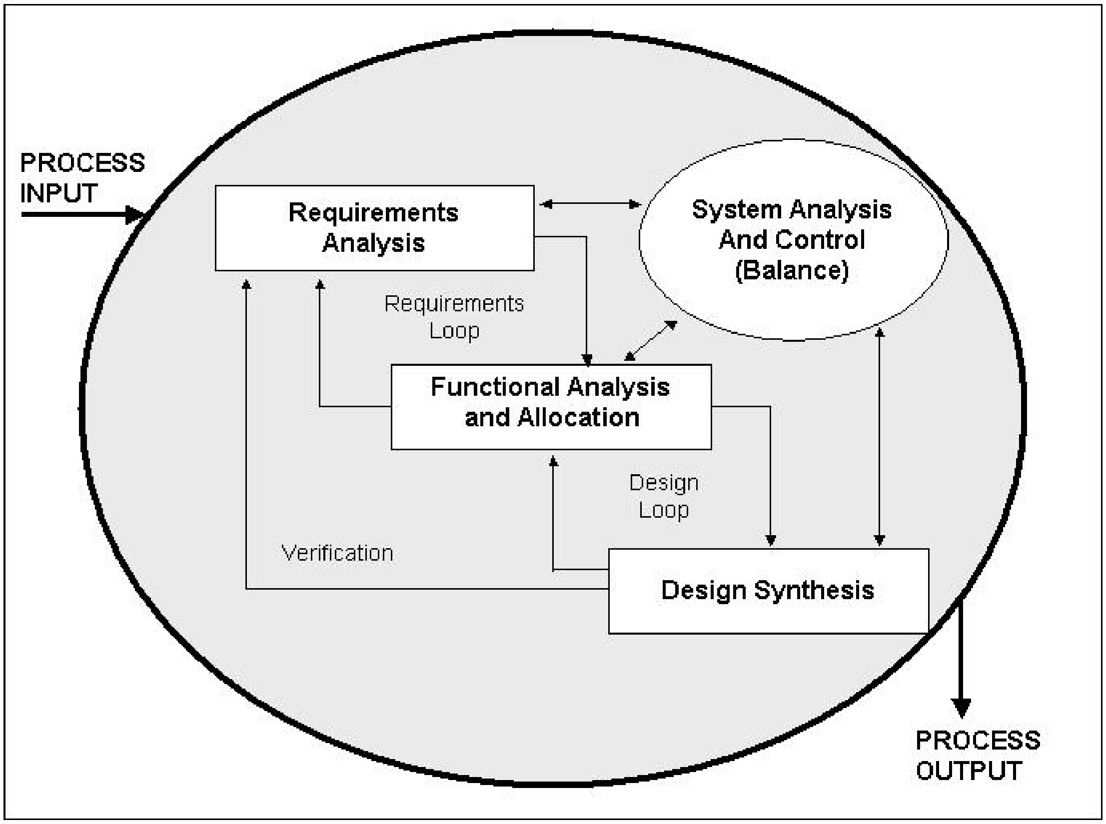

Figure 1. Systems Engineering Process [From Ref. 8]

The Systems Engineering Process (SEP) is the heart of Systems Engineering management and thus is the main focus of this thesis. In the simplest terms the System Engineering Process seeks to take what the customer wants and needs through a methodical process, ultimately providing him with a product or process definition that meets the requirements at a given level of development. Typically during the SEP, architectures are generated to better describe and understand the process. The DoD uses three architectures that describe important aspect of the system: functional, physical, and system. To properly understand how this transformation takes place and where the architectures fit in, the major steps of the SEP are briefly explained below. Also refer to the Figure 1 to assist with the explanation.

The SE Process Inputs consists of the customer's needs, objective, and constraints that come from any number of sources. These inputs are then analyzed during Requirements Analysis to produce requirements that define what the system must do and

how it must perform. The difference between the raw inputs and defined requirements is that requirements are understandable, unambiguous, comprehensive, complete and concise. Functional Analysis/Allocation takes the requirements and allocates functions to them. The higher-level functions are then decomposed to lower and lower levels of functionality. What results is a description of the product in terms of what it does logically and in terms of the performance required. This description is often known as the functional architecture. Functional Analysis and Allocation allows for a better understanding of what the system has to do, in what ways it can do it, and to some extent, the priorities and conflicts associated with lower-level functions. The Requirements Loop is a feedback method that ensures each function identified is traceable back to a requirement, ensuring the allocation effort has been successful. Design Synthesis is the process of defining the system by its physical elements, which together make up and defines the system – in other words, the final proposed product. This physical solution is often referred to as the physical architecture, and at the detailed design level, where all products to support the system are identified, it is known as the system architecture. The Design Loop is another feedback method that insures the physical design can execute the functions at the required levels of performance. The final Verification Loop ultimately ensures that the solution satisfies the original requirements. Systems Analysis and Control is an overarching management tool that applies to all steps in the SEP. It includes technical management activities required to measure progress, evaluate, progress, perform tradeoffs, evaluate and select alternatives, and document data and decisions. Lastly, the final Process Output most often depends on the level of development. In this thesis the process output will be the storage system's physical architecture as well as selected items from the system architecture [Ref 8].

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III. DATA

This chapter is a presentation of four primary sets of data to support further analysis. The results of a "User IPT" are presented first to establish the needs and requirements of the user as it relates to secure storage. Next, information on security standards is presented to gain an understanding of regulatory requirements for secure storage and an understanding of existing secure facilities. Third, since the system must be mobile for deployment, DoD and international compatibility, transportability, and loading requirements/constraints are examined. Lastly, a market review of a variety of commercial systems is conducted to highlight existing features that may benefit the design process.

A. USER REQUIREMENTS

The following customer requirements were gathered using a synergistic "User IPT" approach where eleven U.S. Army officers were brought together to provide input based on their extensive experience as company commanders and Division-level-and-below staff officers. Each of these officers had between six and fourteen years of operational training experience, and each had been deployed to at least one major stability and support operation (SASO) in the Caribbean, the Balkan States, or Southwest Asia. The Army's Armor, Artillery, Aviation, Engineer, Infantry, Military Police, Military Intelligence, Ordnance, and Quartermaster communities were represented in this sample [Ref. 9]. The researcher tasked this IPT with generating requirements for a deployable secure storage system suitable for use by the majority of U.S. Army units. The researcher's intent was for this IPT to develop a preliminary and rudimentary operational requirements document (ORD).

The following statement was provided to the users to begin the session. It listed the shortcomings of existing systems and all the officers concurred with its general accuracy:

> Support facilities requirements are not being considered during the acquisition of soldier system components. Consequence: there currently is, or there will be in the very near future, a shortage of secure storage space in existing facilities. The proliferation of sensitive and valued non-

sensitive items such as small arms accessories, night vision equipment, geo-positional devices, and communications equipment fielded to the force over the past several years has resulted in severe crowding of unit secure storage facilities. As we continue to field a considerable array of new equipment over the next several years, the problem will worsen. Additionally, our storage facilities predominantly employ manual accounting procedures that make issuance, maintenance, and accountability of equipment a cumbersome process. These facilities are not deployable with the unit.

The threat described to the IPT was estimated as small groups (2-10 persons) organized to infiltrate perimeter defenses and target a secure storage system. Their tools to gain access to the secure storage system could include, heavy blunt force instruments, manual cutting instruments, flame-cutting torches, small arms, and explosives. Additionally, a threat from indirect fire munitions was included as well.

Four goals for the secure storage requirements generation IPT session were given to frame the scope of the problem.

- A single system adaptable for both home station use and deployment is preferred.
- A system must be deployable by land, sea, and air.
- A system must meet both current and future secure storage needs (e.g. new acquisitions and equipment modifications).
- The system will provide the greatest operational and logistical convenience possible for using units.

Three basic constraints were provided based on common data concerning Army goals for deployable systems and secure storage facilities at the company level.

- Deployable container must meet ANSI/ISO standards or be able to be easily loaded into an ANSI/ISO container to ensure intermodal capability and be compatible with or be able to be loaded on the 463L air movement system.

  Rationale: Important to ensure that the system can be moved by the largest spectrum of military and civilian transportation assets.

- Must be deployable via U.S. Air Force C-130 cargo aircraft.

  Rationale: Deployment via C-130 is a key component in meeting current "Army Transformation" rapid power projection objectives.

- All components to be used within a standard Army arms rooms must be smaller than the 34 by 83 inch interior envelope of the access door jams [Ref. 58].

  Rationale: Arms rooms are the only common certified sensitive item storage areas within Army tactical units. To prevent expensive construction modifications, sensitive item storage systems must be able to fit within this constraint.

The following are the IPT's requirement recommendations for the missions and the environments where the secure storage system must operate.

- The secure storage system will be capable of operating in all U.S. Army operational and training missions, both in peacetime and in time of war, but will be optimized for Stability and Support Operations (SASO).

  Rationale: The system will be optimized for SASO since the system is most likely to be used in this mission profile. Stability and Support Operations are characterized by deployments of long duration, in static positions, where soldiers often conduct duty in shifts throughout the day and have a storage requirement for their weapons during off-shift periods. Soldiers on deployment in higher intensity conflicts generally keep their weapons and equipment on their person and are ready for rapid movement; therefore, this type mission limits (but does not necessarily eliminate) the need for a forward-deployed security system.

- The secure storage system or its major components will be used both at home station and upon deployment.

  Rationale: To achieve the cost and performance synergies of a total system, it only makes sense to use the same system, or major components thereof, across the full spectrum of possible uses.

- The secure storage system must be an "all weather" system capable of operating in all environmental conditions including arctic, tropical, desert, and all environments in between. It must have overhead protection from environmental conditions when internal storage systems are in use.

  Rationale: The Army is an "all weather force" and it must be prepared to conduct operations wherever called, regardless of weather conditions. To prevent corrosion or damage, all items in storage must be protected from precipitation, even when in operational use.

- The secure storage system must be located so as to be easily available and accessible to the owning commander who is signed for both the system and its contents.

  Rationale: Due to the importance of the sensitive items and valued non-sensitive items contained within a secure storage system, these items must be readily available to the commander for both training as well as rapid deployment. Additionally, the serious consequences associated with the loss of any such items from the storage system makes it paramount that the system, or its major components, be in close physical proximity to the owning commander's administration area to ensure the proper level of security and oversight.

The following are the IPT's functional requirement recommendations for the secure storage system.

- The system must support all sensitive items and valued non-sensitive items normally encountered at Brigade-level and below and be capable of sufficient expansion capacity to meet the unit's secure storage needs over the next 20 years. The physically largest sensitive items that the system is currently expected to support will be the M2 machine gun, the Mk.19 automatic grenade launcher, the Javelin Command Launch Unit (CLU), and the TOW Missile Improved Target and Acquisition System sight.

Rationale: The system must be able to handle all items that are currently a security concern, and have sufficient capacity to handle the likely increased storage needs of future sensitive item systems.

- The system must reduce the cubic space that current storage methods require within existing facilities.

  Rationale: In order to minimize facility modifications and/or military construction (MILCON), existing secure storage within present facilities should be utilized to the maximum extent possible. To have sufficient capacity for future expansion, the current storage footprint must be reduced or these facilities will not be able to accommodate the larger future storage requirement. Additionally, savings in the cubic area consumed by the system ensures less logistical effort to transport it into theater and throughout the area of operations

- The system's components will fit within a standard arms room while in garrison to meet existing sensitive item security regulations. Its construction must be sufficiently robust to be approved for sensitive item storage during transport while under the watch of a security escort.

  Rationale: System must meet physical security standards and procedures for arms and sensitive items in accordance with Army Regulations 190-11, 190-13, 190-51, and Field Manual 55-65.

- The system must be capable of being fitted with an Intrusion Detection System (IDS) to be installed primarily for long-term field usage.

  Rationale: An IDS system will enable the system to be left unsupervised, thereby conserving manpower in the field.

- The system will be automated with information technology to assist and enhance the accountability, issue, and receipt of equipment contained within. Additionally, maintenance actions and records concerning the system's contents will be automated as well.

Rationale: All inventory, issue, and receipt actions involving sensitive and valued non-sensitive items are extremely time consuming and are currently done manually. Any improvement would allow considerable time savings for soldiers and the administrating headquarters. Additionally, most maintenance administrative actions are currently done manually which also takes considerable time.

- The system will be able to accept multiple storage configurations to accommodate different units' various types of equipment while maintaining overall standardized form, fit, and function within a deployable platform. Units will be able to cross-load their equipment with other units storage systems with the assurance of a separate and secure environment within the overall storage system, thus preventing intermingling of the different units' equipment.

  Rationale: The system will be expected to handle a multitude of equipment types since all units have different equipment and have different storage requirements. All equipment must be pre-configured and organized to facilitate rapid loading and subsequent deployment. Army units routinely attach or assign supporting units to other elements and they must be able to rapidly insert their equipment into their new parent organization's secure storage system without concern for confusing their equipment with the parent unit's.

- The fully loaded system must be compatible with, and be transported by, unmodified 5-ton cargo trucks as a minimum. Transportation via 2.5-ton trucks is desirable. Short-range transportation over primary roads via a dolly set is also desirable.

  Rationale: To maximize the transportation flexibility of a division, existing transportation assets common to combat arms and combat support battalions must be used. Dolly sets provide wheels for a container and enable the containers to be towed without the need for a large prime mover.

- Internal components of system used within the arms room must be able to be moved about the arms room and the company area by hand or via human-powered mechanical material handling equipment.

  Rationale: The Army's smallest forklift, the 4000-pound model, is unable to enter and operate within current company storage areas. Additionally, the purchase of even smaller motorized MHE is discouraged due to the additional acquisition and support costs involved.

- The system must have the ability to employ a worldwide movement tracking system, if so desired. As a minimum, the container must have a system for remotely locating the container and identifying its contents at the point of embarkation and debarkation.

  Rationale: Transportation of sensitive items is even more secure when the items can be tracked during transport. Additionally, a movement tracking system will provide visibility of the storage unit and its contents throughout its travels. A container locating system enables the owning or responsible unit to rapidly locate the storage system at the critical points of embarkation and debarkation.

- The system must provide ease of accessibility to all its contents without the need to unload any portion of the system to gain access to otherwise unreachable areas. Additionally, the storage system must maximize its available interior space.

  Rationale: Current "breakbulk" deployable storage systems require repeated unloading and loading to gain access to the entirety of the stored items, as such systems lack any organizational structure to manage interior storage; consequently, much time is wasted in such pursuits. Additionally, traditional stuffing measures leave much wasted interior storage space and are prone to shifting during transport

- The system will require extremely limited blocking, bracing, or banding when fully loaded.

Rationale: Much time, effort, and non-organic resources are required for a unit to block, brace, and band current deployable storage containers to prevent their contents from shifting during transport. Additionally, since the average combat arms and combat support unit is not extensively trained in container loading/stuffing operations, their blocking and bracing efforts may be substandard.

- The system should be able to replace the majority of existing, individual, protective storage cases for sensitive and valued non-sensitive items.

  Rationale: Most sensitive and valued non-sensitive items are issued with their own protective storage cases, which when stored in bulk create storage problems due to their large size in respect to the actual item being protected. The proposed secure storage system should provide enough impact protection to make the continued use of such cases unnecessary, thus saving considerable storage space.

- The system will have components common to both early entry forces and heavier mechanized or armored forces.

  Rationale: Commonality across the Army will increase the system's utility and affordability as well as enabling all types of forces to store their equipment in one another's storage system if this need ever arose.

- The system will have sufficient flexibility to store existing small arms and crew-served weapons with their various sighting/aiming systems and MILES transmitters attached or mounted. Additionally, the system must be able to accommodate future arms such as the Objective Individual Combat Weapon (OICW) and its Crew-Served counterpart (OCSW) without significant modification.

  Rationale: Current arms racks can limit the amount and type of sighting/aiming systems that can be stored mounted on the weapons requiring their removal prior to storing. Additionally, modifications have to currently be made to accommodate the small differences between the

M16 and the M4 Carbine storage racks, and new generations of weapons will require totally new storage racks. It makes sense to try to accommodate all within the same storage system envelope to prevent continued modifications and new procurements of weapons racks.

- The system will have a portable workspace and tool storage for the unit armorer.

  Rationale: Although the armorer has a standard toolkit, he/she has no standard workspace. The armorer typically fabricates such a workbench in garrison, which is rarely transportable to a field environment where it is needed as much or more since that is the location of the majority of weapons malfunctions.

- The system will have openings and fixtures to accommodate intake and exhaust of Heating, Ventilation, Air Conditioning (HVAC), and a dehumidifier that do not compromise overall security.

  Rationale: Although an HVAC opening may not be necessary for common secure storage needs, it will increase the overall flexibility of the storage unit. The dehumidifier is a necessity to prevent rusting of weapons and equipment in damp environments. A direct drainage system will prevent the manual disposal of accumulated water.

- The system must have connections for an external electrical power supply. There must also be auxiliary internal power outlets for other electrical appliances used within the system.

  Rationale: Electrical power will be needed to operate such items as internal lights, an IDS, a dehumidifier, HVAC, and other unforeseen uses.

- The system will have physically robust internal lighting fixtures. Connections to the light fixtures must have an automatic mechanism to select red light versus white during limited visibility.

Rationale: The system must use red light during tactical situations and periods of limited visibility to prevent easy visual identification by threat forces.

The following requirements were not generated by the IPT, but were selected from an Operational Requirements Document (ORD) for an Authorized Stockage List Mobility System. This system has some general similarities to the Secure Storage System. These requirements are generic in nature but applicable and important for consideration for the secure storage system [Ref. 10].

- The system shall have high reliability and maintainability characteristics. The system must maintain a fully mission capable readiness status using he Army's standard maintenance system. Unit personnel will perform unit maintenance with organic tools. Unit level maintenance will consist of periodic inspection for mechanical integrity; lubrication; and maintenance of door assemblies, floor, roof, and sides. Additionally, any internal storage systems must be robust, reliable, and able to be easily maintained.

  Rationale: As a container system, the secure storage system should have minimal maintenance requirements at the organizational and direct support (DS) maintenance levels.

- The system will not create the need for additional operators or maintenance personnel.

  Rationale: Conserves resources and limits life cycle costs.

- The system design, to include controls, displays, configuration, required operating and maintenance procedures, and operating environment will minimize human performance errors, interface problems, and workload requirements. The user interface should be uncomplicated and respect appropriate design guidance in MIL-STD-1472. The system shall be designed for use by the 5^{th} percentile female through the 95^{th} percentile male soldier to promote ease of use. The system must be compatible with the range of environmentally protective clothing.

Rationale: The system must be easy to use for the majority of soldiers in various environments and conditions.

- The system will be designed in accordance with all applicable system safety standards so as to minimize safety risks associated with operating and maintaining the system. All safety hazards will be eliminated or reduced to an acceptable level of risk.

  Rationale: Safe operation is paramount.

B. SECURITY STANDARDS

1. Arms Storage Facilities

Army Regulation 190-11 governs the physical security of U.S. Army arms, ammunition, and explosives. The totality of this section is drawn from that regulation. However, this research is primarily concerned with the security of arms, as the Army typically does not store bulk ammunition or explosives within a tactical unit. The Army classifies its arms into four storage risk categories [Ref. 11]:

- Category I includes complete, ready-to-fire, man portable missiles and rockets. An AT-4 anti-armor weapon is an example, as is a fully configured Javelin missile. As with ammunition and explosives, such items are not typically stored within a tactical unit's facilities.
- Category II is the highest security storage category commonly encountered. It includes such weapons as light, medium, and some heavy small arms and crew served weapons. The M249 SAW, the M240 MG, the M16/M4 serious of weapons, the M2 .50 caliber MG, and the Mk.19 40mm Automatic Grenade Launcher are all in this category.
- Category III includes such weapons as all non-ready to fire missile or rocket launch tubes and their separate firing assemblies, mortar tubes, and grenade launchers.
- Category IV includes all non-fully automatic shoulder-fired small arms and handguns.

All risk categories require a fixed facility secure storage area whose construction is specified by the AR 190-11. For this research, all previous or future construction of fixed, secure facilities meets these requirements. The requirements for security of arms within the fixed secure facility are as follows [Ref. 12]:

- When not in use, arms will be stored in banded crates, metal containers, approved standard issue racks or locally fabricated racks. Fabricated racks will provide, at a minimum, security equivalent to standard issue racks. Standard issue approved metal wall lockers or metal cabinets may be used. Crates or containers will be banded, locked, or sealed in a way that will prevent weapon removal without leaving visible signs of tampering. Screws or bolts used in assembly of racks, crates, or containers will be made secure to prevent disassembly.
- All arms racks or container will be locked with approved secondary padlocks. All racks or containers must ensure that weapons cannot be disassembled within the rack or container and subsequently removed.
- In facilities not manned 24 hours a day, all racks or containers weighing less than 500 pounds must be secured to the structure or fastened together in groups totaling more than 500 pounds with bolts or chains equipped with secondary padlocks

The security features or characteristics that must be included in secure storage that does not meet fixed facility security standards, yet where a comparative level of security is desired, must include the following [Ref. 13]:

- Category II-IV arms must be stored in a General Services Administration (GSA) approved, Class 5 security container such as a safe-type filing cabinet, or a modular steel vault that does not contain classified documents or materials. A Class 5 security container must provide a minimum of 15 minutes of protection against a multilevel tool attack [Ref. 14].
- An approved intruder detection system (IDS) must be present and a security patrol must check the facility at least every 8 hours. Without the

IDS the facility must be guarded 24 hours a day by an armed sentry if it contains Category II arms. With Category III and IV arms only constant surveillance is required if there is no IDS. The IDS includes both interior and exterior detection systems that report directly to an alarm monitoring station.

- Arms racks or containers will be locked with approved secondary padlocks. All racks or containers must ensure that weapons cannot be disassembled within the rack or container and subsequently removed.
- In facilities not manned 24 hours a day, all racks or containers weighing less than 500 pounds must be secured to the structure or fastened together in groups totaling more than 500 pounds with bolts or chains equipped with secondary padlocks
- Access doors must have approved high security locking devices. The most secure door in systems with double-door protection will utilize the most secure lock.
- When mobile containers are used their vulnerability must be assessed and they must be placed where they are least likely to be able to be moved by unauthorized persons with heavy lifting equipment.

2. Arms In Transit

Arms can either be securely transported by their unit or via civilian contractors. The standards for the transportation of arms by their unit follow [Ref. 15]:

- Categories I and II arms will be placed in the custody of a commissioned officer, warrant officer, noncommissioned officer (E-5 and above), or a DoD civilian (GS-5 and above).
- Category I arms will be provided armed guard surveillance. Category II arms will be provided armed guard surveillance provided State or territorial law does not prohibit the arming of the guards, and then a waiver for such a policy will be requested.

- Bulk shipments of arms will be placed in approved shipping containers, for example CONEX, MILVAN, and SEAVAN. The container must be secured with approved locks. Containers will be placed door-to-door or door-to-immovable object to prevent unauthorized entry.
- A detailed packing list and serial number inventory will be placed within the container for inventory purposes.

Security standards for the transportation of Category II arms and below by civilian contractors follow [Ref. 16]:

- Via ground transport
  - Exclusive use of vehicle
  - Satellite motor surveillance service
  - Dual driver protective service with national agency check
  - Locked and sealed by contracted shipper
  - Single line-haul required
- Via rail transport
  - Rail surveillance system
  - Military traffic expediting service
  - Locked and sealed by shipper
  - Immediate notification of consignee upon delivery
  - For flatcar transport use only approved shipping containers, for example CONEX, MILVAN, and SEAVAN. The container must be secured with approved locks. Containers will be placed door-to-door or door-to-immovable object to prevent unauthorized entry

- Via air transport
  - DoD constant surveillance system
  - Shipper escort to the carrier and immediate pickup at the point of destination.
  - Container banded or locked
  - Seals applied by shipper
- Via water transport
  - Pier service only
  - Written receipt from ship's officer at port of embarkation and written release to carrier at port of debarkation

3. Unclassified Sensitive and Valued Non-sensitive Item Storage Facilities

The level of security of unclassified sensitive and valued non-sensitive items is based on a risk analysis dictated by DA Form 7278-R and DA Pamphlet 190-51 and conducted by representatives of the installation commander, the using unit, and the supporting provost marshal (military police authority) [Ref. 17]. This risk assessment weighs the mission criticality, replaceability, and relative value of the item and compares this to the relative sophistication of the threat and the likelihood the threat will pursue a given course of action. The three risk levels run from I to III with Risk level III being the highest of the three. This risk assessment must be done when a unit is activated, when it relocates to a new site or facility, at least every 3 years, or when an incident occurs in which an asset is compromised. The primary sensitive and valued non-sensitive items a tactical unit might be most concerned about would be communications equipment; night vision devices; secondary weapon sights, nuclear, biological, chemical detection devices, equipment parts and spares in the authorized prescribed load list (PLL); and unkeyed controlled cryptographic items (CCI). For this research the standards for risk level III must be achieved since the system will be mobile and thus could be used in the worst-case scenario. These standards include [Ref. 18]:

- Portable items must have double barrier protection. Examples of double barrier protection would be a locked steel cage or a free-standing locked container within a secure storage structure. Additionally, securely affixing the item to the internal structure of a secure storage structure meets the double barrier standard.
- Portable and easily pilfered items must be stored in a separate locked secure room, area, or container with controlled access.
- There area must be lighted during hours of darkness.
- No landscaping features greater than 12 inches high that may give concealment are allowed with 20 feet of the facility
- An IDS will be installed around or on the storage room, area, or container.

4. Unclassified Sensitive and Valued Non-sensitive Items In-transit

Army Regulation 190-51, Security of Unclassified Army Property (Sensitive and Non-sensitive) does not include information on transporting sensitive and non-sensitive items; however, it does mention the in-transit security of controlled medical substances and other medically sensitive items. It says, "In-transit security must be such that the spirit and intent of this regulation are not violated and that these sensitive items are protected from unauthorized possessions, use, and theft." The same standard would seem to reasonably apply to the full array of unclassified sensitive and valued non-sensitive items [Ref. 19].

C. TRANSPORTATION CONSIDERATIONS

1. Intermodal Transport Compatibility

One of the key requirements for the secure storage system is that it be mobile. It must be able to be deployed to major training exercises and contingency operations as rapidly and efficiently as possible. Since the secure storage system could feasibly move via road, rail, sea, or air a review of intermodal systems is required to ensure compatibility of the system with established commercial and military transportation systems.

Intermodalism is the transshipping of cargo among two or more modes of transportation. In concert with intermodalism, containerization facilitates and optimizes carrying cargo via multiple modes of transport (sea, highway, rail, and air) without intermediate handling of contents" [Ref. 20]. Intermodal capability and containerization is important to DoD as the effective implementation of both increases the seamless flow of materials and information; mobility and readiness; throughput distribution; standardization; in-transit visibility; and cargo integrity, security, and safety [Ref. 21]. These characteristics greatly increase the responsiveness of U.S. forces and enable rapid power projection through the use of both DoD and commercial transportation assets.

The overarching policy for DoD intermodal containerization comes from DoD Regulation 4500.9-R-1. It says that DoD components shall:

- Establish container-oriented distribution systems
- Use such systems to move supplies and equipment
- Use commercial industry
- Ensure system interoperability

Even without such a policy, the U.S. Army's new vision of "Transformation" would seem to be quite impossible without the effective use of commercial shipping. Although the Army's Chief of Staff demands that a combat Brigade be deployed in-theater within 96 hours and a Division within 120 hours, the bulk of such early Brigade deployments would be accomplished primarily through air transport. However, there is a final requirement to have five Divisions deployed within 30 days [Ref. 22], which would be quite impossible without the use of commercial sealift. There is just not enough Air Force or commercial air capacity available to accomplish such a Herculean task. Since the Army has the largest requirement of all services for strategic lift, it must maximize its use of containerization to facilitate rapid deployment - especially through the use of sealift. The Army must look towards commercial shipping to meet its deployment needs, as this is the primary transportation variable that has changed since DESERT STORM – largely due to the advent of the Voluntary Intermodal Sealift Agreement (VISA). VISA provides the DoD with a modern, efficient, and capable intermodal transportation

network through pre-negotiated contracts with U.S. shipping companies [Ref. 23]. As a result, there has been a 134% increase in sealift capacity since DESERT STORM while airlift capacity has increased a mere 2% [Ref. 24].

The U.S. Army's Field Manual for container operations, FM 55-80, dated 13 AUG 1997, stresses, "Containerization increases the types of ships available to support strategic deployment as well as increasing the cargo capacity of other available ships. It also streamlines handling requirements within the distribution system, increases protections against shipping damage, and safeguards against pilferage." The manual goes on to say, "The Army's goal is to increase the use of containers to improve the use of strategic lift and improve force closure for unit equipment and sustainment supplies. The Army must adopt a container system that is interoperable with both Service components and commercial industry" [Ref. 25]. In effect, the official publications mandate that if the Army desires to move cargo like the rest of the world, it must adopt commercial containerization practices to the greatest practical degree.

Two basic types of systems characterize intermodal containers. The first is a commercial system known as the American National Standards Institute/International Organization for Standardization (ANSI/(ISO) container systems - from hereon to be known simply as ISO containers. The second is a U.S. Air Force system, the 463L Air Transport System.

Most ISO containers (frequently known in the military as CONEXs, MILVANs or SEAVANs) have square, boxlike configurations to promote ease of stacking within ships or on shore, and are standardized at their width – all being 8 feet wide. The other primary standardization feature is the "twist lock" connection fitting on all corners of the container. This common connector interface allows the container to be firmly grasped by a wide array of material handling equipment (MHE), enables containers to be adjoined to one another, and also locks them onto transportation assets (towed container chassis, rail car, etc.).

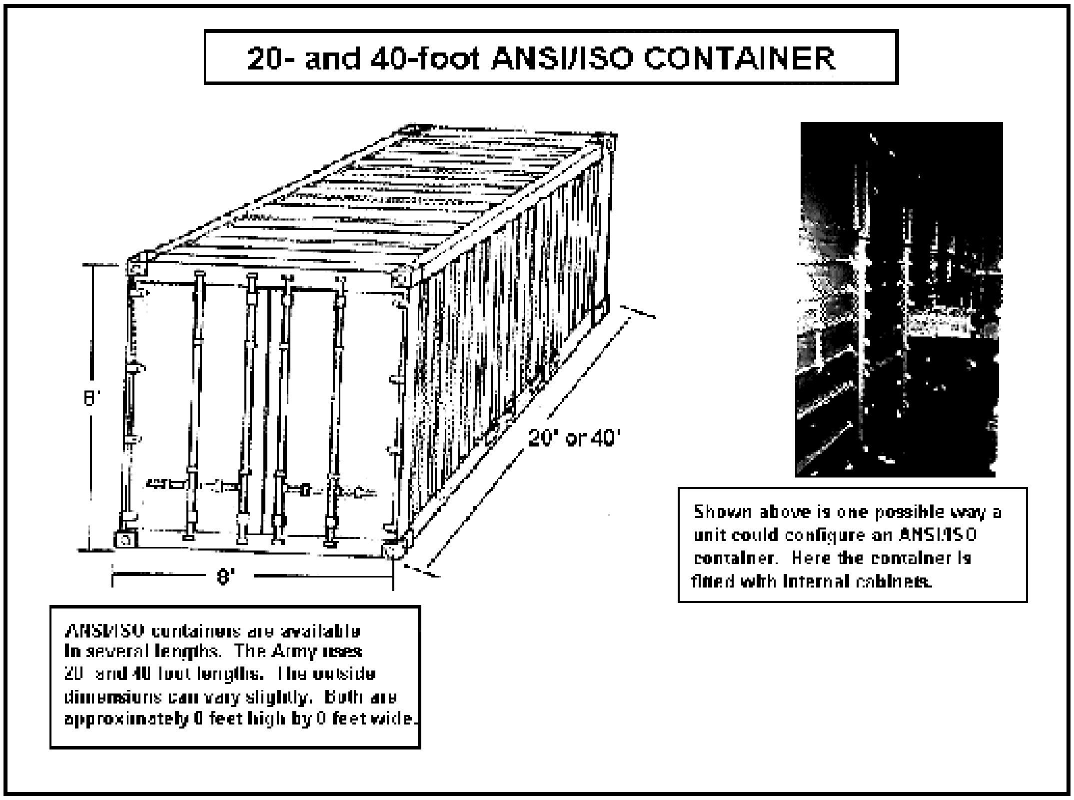

Figure 2. ANSI/ISO Container [From Ref. 26]

DIMENSIONS (inches)		20-foot ISO	40-foot ISO
Internal	Length Width Height	230.9” 91.7” *	472.3” 91.7” *
External	Length Width Height	238.5” 96” 96” and 102”	480” 96” 96” and 114”
Door	Width Height	90” 83.5-89.5”	90” 83.5”-101.5”
Max Gross Weight		52,900 lbs	67,200 lbs
* Maximum height is external height minus 9.5”			

Table 1. ISO Dimensions [From Ref. 27]

The DoD uses two standard lengths for its ISO containers, 40 and 20-foot units. The 20-foot (actually only 19 feet, 11 inches long to enable two to be joined to

make a 40-foot unit) unit is the preferred container for the full continuum of DoD container operations as it fits the widest array of MHE and transport mediums; however, the 40-foot unit is typically more economical to ship, costing an average of only 10% more to ship via commercial carrier than a 20-foot unit. (Ref. Joint Intermodal Working Group Brief). The DoD's stated goal is to ship unit equipment primarily in 20-foot containers and sustainment supplies in both 20 and 40-foot ISO containers [Ref. 28]. It should be noted that there are ISO containers that are smaller than 20-foot units, but they typically can be configured in Twenty-foot Equivalent Units (TEU). For instance, the Army has a few "TRICON" and "QUADCON" containers that when three or four respectively are joined together using connectors on their corner fittings, they essentially become one TEU.

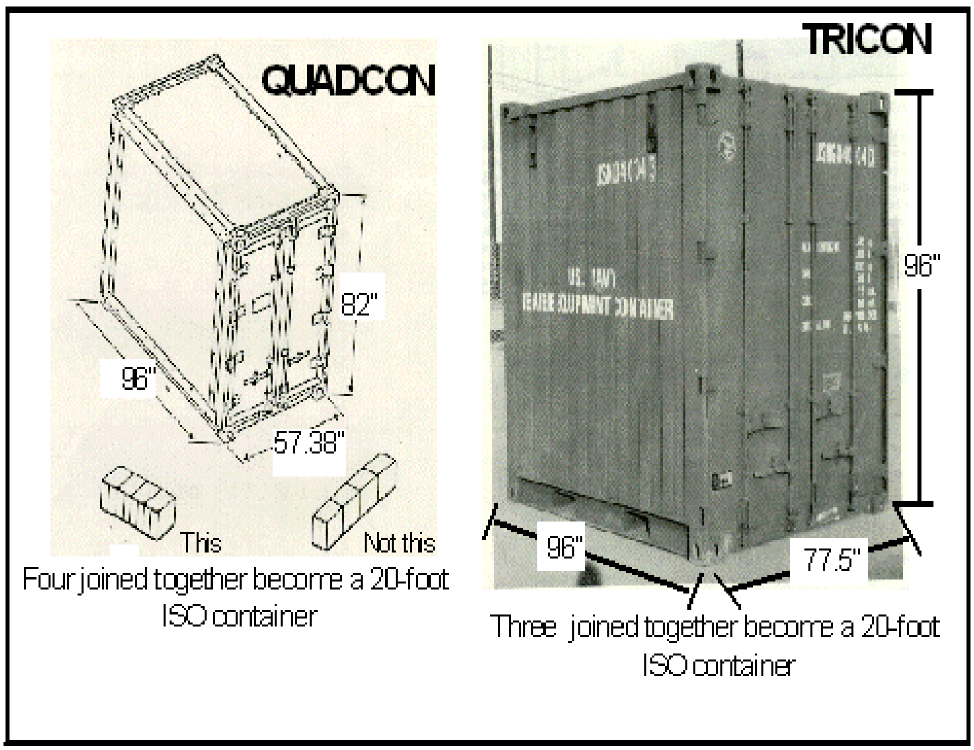

Figure 3. TRICON and QUADCON Containers [From Ref. 29]

The Army has a preference for the TEU. In fact, during a recent operation in the Balkan area of operations, a Headquarters, U.S. Army, Europe message mandated that all container shipments be configured and shipped in 20-foot containers as the theater was unable to receive, stage, or provide onward integration of 40-foot containers due

severe limitations of cargo handling equipment [Ref. 30]. This preference for the shorter container is primarily a result of the Army's standardized artillery ammunition and rocket resupply system, which uses this size of container exclusively on its Palletized Loading System (PLS) trucks for rapid loading, unloading, and movement.

The commercial shipping industry has a preference for 40-foot and longer containers, as these tend to offer the greatest overall efficiencies. Consequently 20-foot containers now make up only about 23% of the available commercial container pool. Additionally, although 23% of all containers would seem to be a large number, the pools of 20-footers are not evenly spread throughout the world, leaving the potential for severe regional shortages being created shortages during deployment surges [Ref. 30]. Lastly, it takes, on average, seven days to request and receive commercially leased containers [Ref. 31].

One last characteristic of ISO containers that should be highlighted is that they are heavy. An average commercial 20-footer will average between 3,800 and 5,555 pounds [Ref. 32]. Such a healthy weight considerably limits the container system's maneuverability and mandates robust MHE and transportation assets at all levels.

2. Air Transport Compatibility

As mentioned above, air transport constitutes one of the legs of intermodalism, yet it is the most restrictive due to aircraft payload limitations on weight and size. Additionally, there are a very limited number of cargo aircraft available to U.S. military forces as compared to other intermodal transportation options.

Despite these limitations, air transport does provide the most rapid means of deployment; therefore, it is the method of choice for rapid movement of troops and equipment – typically in the early phases of operations. The Army's Transformation requirements demand that all future Army systems fit within the cargo-carrying envelope of the C-130 tactical cargo aircraft [Ref. 22]. The C-130 is a tactical aircraft versus a strategic air lifter in that it conducts most of its missions within a theater of operations rather than executing long flights to transport U.S.-based forces from CONUS to the theater of operations. Thus the C-130 is a smaller and more flexible aircraft, able to land on relatively short and unimproved airstrips. This capability is thought to be essential to

complement the new doctrine and the capabilities of the Army's Interim Brigade Combat Teams and the subsequent Objective Force. Of course anything that will fit into a C-130 aircraft can more easily fit within larger Air Force cargo aircraft such as the C-141, C-5, and C-17, so universal compatibility is ensured.

The U.S. Air Force has standardized method for loading, transporting, and unloading cargo within its aircraft: the 463L cargo system. The 463L cargo system includes the pallets, nets, MHE, and aircraft rails and roller system. The rails and rollers of the 463L system consists of rows of rollers and rails that allow the palletized cargo to be easily moved into the aircraft [Ref. 33]. The standard 463L pallet really appears to be no more than a thick, flat piece of aluminum with serrated edges - although it actually has a wood core sandwiched between the aluminum. Almost any cargo under 10,000 pounds and 96 inches can be loaded onto the pallet as long as it can be contained and secured by the accompanying net system [Ref. 34 & 35].

The other type of 463L compatible system is the Internal Airlift or Helicopter Sling-able Container Unit (ISU) that is essentially a rigid, six-sided 463L pallet. Typically these weatherproof containers will come in 60" or 90" heights and so are referenced as an ISU-60 or ISU-90 respectively. The ISU, despite its similarity to a small ISO container, is much lighter and does not meet ISO structural standards so it cannot be stacked as ISO containers can. This being the case, they cannot be moved on container ships unless carried as secondary loads or within a larger ISO container. An additional feature of the ISU container is that it is certified for both internal and external (slingload) helicopter transport [Ref. 36].

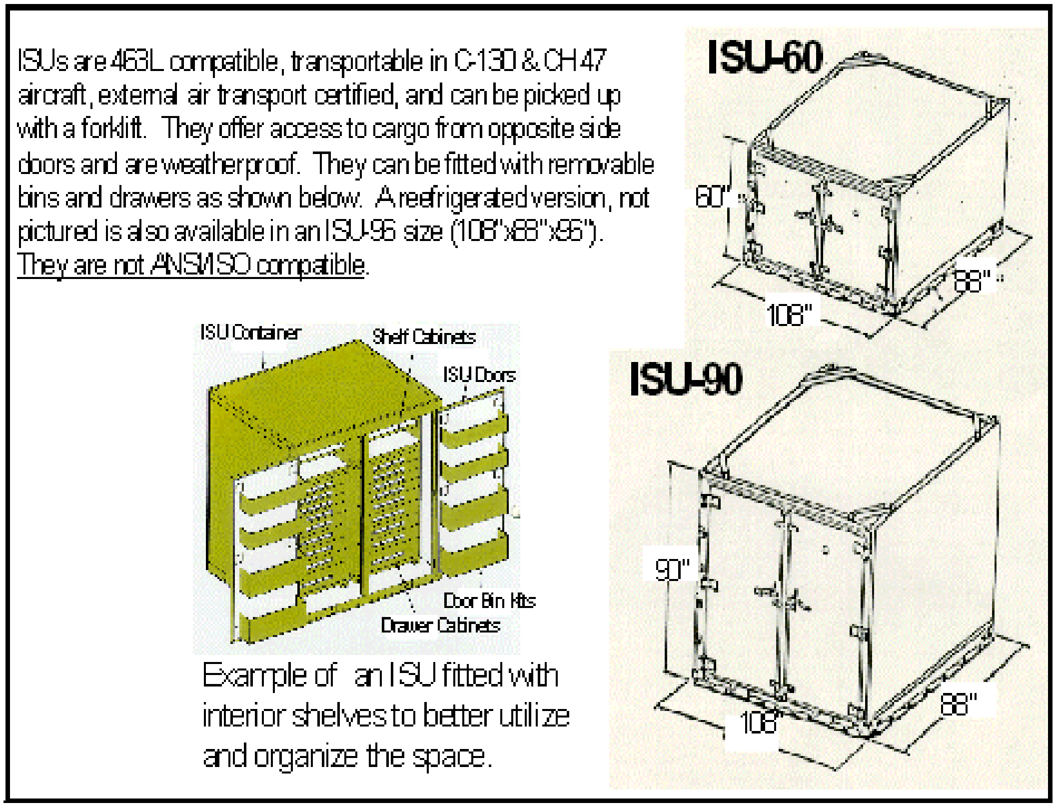

Figure 4. ISU Containers [From Ref. 29]

The user is ultimately responsible for building 463L pallets, not the Air Force, and may be responsible for loading them onto aircraft. Although the using units must purchase ISU containers, 463L pallets are available to units planning or executing an air movement (through their transportation office) from the U.S. Air Force Air Mobility Command [Ref. 37]. However, most rapidly deployable Army units maintain large stocks of these pallets on hand.

It should be noted that standard ISO containers can indeed be utilized within Air Force cargo aircraft. Even the 20 foot ISO container is capable of being transported via the C-130. However, all ISO containers must first be placed on one or more 463L pallets before being loaded onto an aircraft [Ref. 37]. Conversely, ISU containers can fit within an ISO container if their height is limited to 83 inches ("shoe" and "slipper" concept). If the ISU container is to be used in the container while mounted on a flatrack, the ISU can be no higher than 80 inches [Ref. 38].

While the lighter ISU container is generally considered to be a tool of the Army's light infantry, airborne, and air assault units, it has begun to be purchased by the forward

deployed mechanized and armored units in Europe, where transport via sealift is far less likely than CONUS based forces [Ref. 39].

Lastly, the use of the ISU-90 for secure storage is not currently recommended. It is not certified for such use and recent experience in the Balkan states reveal that ISU-90s were broken into extensively and their contents stolen, thus requiring 24-hour supervision by armed guards [Ref. 40]. However, a personal interview with a commander who served in the Balkans suggests that the primary failing of the ISU-90 is not with its slight construction, but rather with its lack of a high-security locking hasp to protect the standard 5200 series military padlocks used to secure the container. This type of lock, left unprotected, is easily cut with standard bolt cutters [Ref. 41].

3. Ground Transportation Constraints

Army Divisions do not have large quantities of medium or heavy transportation assets, nor do they have large quantities of material handling assets. Instead, the Army relies on their higher echelons of support at Corps and Theater level for significant amounts of these resources. Since many of these higher echelon support units are co-located with the Divisional units at any given Army post, their availability to the Division during training and operations may be enhanced. However, even the Army's heaviest Divisions and their subordinate units have few assets able to efficiently lift and transport ISO containers, while Light Infantry, Airborne, and Air Assault Divisions have almost no such capability.

Army Trucks Capable of Transporting 20-foot ISO Container		
Truck Type	Cargo Weight Capacity	Comments
M1088A1 FMTV Tractor	Towed load 60,000 lbs	• Transports containers on flat bed stake and platform trailer • Cannot self-load container • 103 flat bed trailers in DISCOM
HEMTT Load Handling System (LHS)	66,000 lbs	• Specifically for handling 8' x 8' x 20' ISO containers and flatracks • Self-upload and download capability • C-130 transportable • Just being fielded
Palletized Load System (PLS)	88,000 lbs	• Specifically for handling 8' x 8' x 20' ISO containers and flatracks • Self-upload and download capability • Primarily operated by Artillery units not support units. 54 in DIVARATY, 9 in DISCOM

Table 2. Army Trucks Capable of Transporting 20-foot ISO Container [From Ref. 42, 43, & 44]

The best assets the heavy Division and the new Interim (medium) Brigades have for moving containerized cargo is the Palletized Loading System (PLS) and the Heavy Expanded-Mobility Tactical Truck – Load Handling System (HEMTT-LHS) trucks. The PLS and LHS are tactical trucks and trailers with integral self-load and unload capability using demountable cargo beds (flatracks) or ISO type containers. Both trucks have the same hydraulic load handling system that mechanically pulls the flatracks or container onto the system when loading. ISO containers can either be mounted on one of the flatracks or a device called a Container Handling Unit (CHU) can be affixed to the end of any 20-foot ISO container.

The PLS is primarily used as an ammunition supply system for Artillery units. Consequently, the Division Artillery has 54 of these systems compared to only 9 in the Division Support Command (based on a Division XXI Table of Organization and Equipment) [Ref. 44]. Thus, what appears to be an abundant MHE and transportation asset cannot be counted on to do logistical container work.

The LHS is just now being fielded to the Army. Fortunately, it will primarily be fielded to combat service support units.

Figure 5. HEMTT LHS with Trailer [From Ref. 43]

The most plentiful Division-level transportation assets are the 2.5 ton and 5 ton Family of Medium Tactical Vehicle (FMTV) trucks organic to the combat arms and combat support battalions in addition to the DISCOM. Many of these trucks have their own Material Handling Crane (MHC) to facilitate self-loading. However, the new Division XXI table of organization (May 97) has taken most of the organic truck assets from the combat arms battalions and moved them to the DISCOM. Combat arms battalions used to have support platoons with M977 or M985 cargo HEMTTs, which had a significant haul capability, but this is no longer the case (see Table 3).

Common Modern Army Cargo Trucks		
Truck Type	Cargo Weight Capacity	Comments
M1078A1 FMTV 2.5 ton Cargo	5,000 lbs	• Cargo bed 12.5' x 7.5' • 10 in Div XXI Infantry Heavy Combat Arms Battalion
M1083A1 FMTV 5 ton Cargo	10,000 lbs	• Cargo bed 14' x 7.5' • None in Div XXI Infantry Heavy Combat Arms Battalion
M1084A1 FMTV 5 ton Cargo w/ MHC	10,000 lbs	• Cargo bed 14' x 7.5' • MHC rated for 5000 lbs • 3 in Div XXI Infantry Heavy Combat Arms Battalion
M977 HEMTT w/ MHC	62,000 lbs	• Cargo bed 18' x 8' • MHC rated at 2500 lbs • None in Div XXI Infantry Heavy Combat Arms Battalion
M985 HEMTT w/MHC	68,000 lbs	• Cargo bed 18' x 8' • MHC rated at 5400 lbs • 99 total cargo HEMTTs in DISCOM • None in Div XXI Infantry Heavy Combat Arms Battalion

Table 3. Common Modern Army Cargo Trucks [From Ref. 42, 43, & 44]

The bulk of the MHE available to the Force XXI Division consists of various forklifts and cranes belonging primarily to the Division Support Command (see Table 4). Unfortunately, such MHE is almost totally absent from ground maneuver combat brigades. Additionally, the Division does not own any forklifts capable of lifting a loaded 20-foot ISO container.

Common Army Material Handling Equipment		
MHE Type	Lifting Capacity	Comments
4K Rough Terrain Forklift	4,000 lbs	• Designed to stuff or unstuff containerized cargo • Deployable within 20-foot container • 10 in DISCOM
6K Variable Reach Forklift	6,000 lbs	• Boom can extend to 21 feet • Cross-country mobility • 21 in DISCOM
10K Rough Terrain Forklift	10,000 lbs	• 3 in DISCOM
10K All Terrain Lifter Articulated System (ATLAS)	10,000 lbs	• Boom can extend to 21 feet • Cross-country mobility • Newest MHE in inventory • 8 in DISCOM, 5 in AVN BDE
7.5-ton Crane w/ cab	15,000 lbs	• 3 in DISCOM
Rough Terrain Container Crane (RTCC)	44,800 lbs @ 27-foot boom radius 80,000 lbs @ 10-foot boom radius	• Theater and Corps level asset • Largely being replaced by RTCH • Cross-country mobility
Rough Terrain Container Handler (RTCH)	53,000 lbs	• Theater and Corps level asset • Can lift and transport 20-foot and 40-foot containers when equipped with top handler device • Cross-country mobility
Container Handling Unit (CHU)	36,250 lbs	• Device that mounts on end of 20-foot container and allows LHS or PLS to upload the container without a flatrack

Table 4. Common Army Material Handling Equipment [From Ref. 44 & 45]

One remaining piece of MHE that should be mentioned is the Rough Terrain Container Handler (RTCH). This large vehicle is used almost exclusively to lift and transport 20-foot ISO containers over short distances. Although this is not a division asset, there is much discussion concerning adding it to the Division's Table of Organization due to its extreme efficiency in moving containerized supplies and equipment on and off trucks, trailers, and railcars [Ref. 46].

D. MARKET SURVEY

Surveying government and commercial storage systems is a prudent step in developing an affordable and innovative secure storage design. The requirement for a mobile secure storage system has been valid for quite some time and ad hoc measures have been undertaken to meet the requirement for the most part. However, industry has begun to respond to this requirement and there are several companies who currently market some form of containerized secure storage system.

1. Secure Storage Methods used During Recent Deployments

As a precursor to surveying the commercial market it is worth examining the typical U.S. Army ad hoc secure storage remedy used during recent stability and support operations. The following information concerning improvised secure storage is based on input from personal statements from officers participating in stability operations from Haiti to Kosovo.

By far the most common method used for creating a field expedient secure storage facility when no fixed facilities are available or adequate, is the placement of weapons and secure items within dry cargo ISO intermodal containers or within ISU containers. This usually involves removing the small arms racks used in the unit arms room, transporting them with the unit to the operational area, and then spot welding or chaining them into the interior of the container. Once the racks are affixed, the arms can be placed in the racks and the container sealed and locked. Additionally, it is common to see commercial grade lockable metal cabinets, such as the Stanley Vidmar brand, installed in such containers as well. Although not suitable for arms security, these cabinets have sufficient security for many valued non-sensitive items. Due to the lack of an IDS system, however, there must be an armed guard posted on this "secure" storage arrangement at all times, as simple bolt cutters can easily gain access to the container's contents [Ref. 9].

One clear advantage to this type of ad hoc system is the low cost. The average costs for a used (approximately 8 years old) 20-foot dry cargo ISO container is only $1,650, while a new container costs an average of $2,900. The cost to lease an ISO container runs, on average, an extraordinarily low $1.33 per day [Ref. 47 & 48]. A plain

ISU container is a more expensive container alternative at $9,162 [Ref. 49]. Since the unit already owns the weapons racks there are no additional costs, except possibly for additional chains and locks.

2. AAR Cadillac Manufacturing's High Security Container

AAR Cadillac Manufacturing, Cadillac, Michigan, is the lead manufacturer of the ISU type container. After numerous requests for a container that could be used to store sensitive items, especially small arms, the company introduced their ISU-90I High Security Container (HSC) in 2001. This container is a standard-size ISU-90, but is made of steel versus aluminum and balsa wood. It is fitted with supplemental armor plate and uses high security hasps and padlocks on its door. The concept for its interior storage mimics that of the ad hoc storage solution: standard weapons racks secured all around the interior walls of the container. It also uses a rack mounted along the centerline of the container to accommodate even more weapons (see Figure 6). This container can hold up to 300 M-16A2 rifles or 272 M-16A2s and 6 M-60 machine guns. It is fitted with a power distribution system, interior electrical outlets and lights, a dehumidification system, and an optional security alarm system. It currently lists for $65,409 [Ref. 49].

Figure 6. ISU-90I High Security Container [From Ref. 49]

3. BOH Environmental, LLC's Field Pack-Up (FPU) System

BOH Environmental, LLC of Chantilly, Virginia, calls its cargo system the Field Pack-Up (FPU) system. The FPU system uses a unique modular container system to enhance cargo organization, which subsequently creates large reductions in the cargo's logistical footprint. The basic system uses a 20-foot, side-opening, ISO-compatible container. The container uses 10 modular cabinets that are loaded back to back into the container, and consume almost its entire interior space, thereby maximizing its utility. When installed in the side-opening container, these modules face outwards on both sides, thereby allowing full access to the entire contents of the container. The modules also lock into the floor when mounted in the container, thereby eliminating the need for interior blocking and bracing. They have a high security module that can hold up to 40 M-16A2 rifles (see Figure 7) [Ref. 50].

Figure 7. Field Pack-Up System with High Security Module [From Ref. 50]

The following is a brief summary of one units experiment with the FPU system. The 21st Theater Support Command's 512th Supply Support Activity (SSA) conducted an evaluation of the FPU as a PLS-mobile warehouse to determine what efficiencies could be achieved through such a system.

The 512th's primary cargo utilized in this evaluation was their Authorized Stockage List (ASL), which consists of variety of classes of supply intended to replenish a brigade size unit. The 512th SSA formerly carried their ASL in 4 M129 vans. The M129 is a 30-foot long enclosed trailer pulled by a 5-ton tractor truck with a notoriously

poor reputation for both overall mechanical reliability and off-road mobility. In order to make the contents of such a container acceptably accessible, much empty space must be provided for a personnel walkway within the container's interior. By carefully repacking their ASL into the modular cabinets, the 512th found they were able to load approximately 81% of the contents of the four trailers into one 20-foot FPU while having 100% accessibility to all their parts and supplies. Another benefit was rapid upload and offload. All the FPU's modules could be loaded from a warehouse into the FPU within only 30 minutes with a 4000-pound forklift. Lastly, the 512th discovered that almost no shifting of the modularized contents occurred when the FPU was transported in the field on the PLS truck during the evaluation [Ref. 40].

The FPU system does have a few negative features. Chief among these is its system cost. If 10 high security arms storage modules were purchased at their individual price of $13,793, the total system cost for the 20-foot FPU unit would exceed $160,000. (Ref. Ed Payne e-mail) Additionally, the units found that although the access to the contents of the container could not have been better, and its interior space was certainly maximized, the user and the pull-out drawers of the modules were exposed to the elements during use. This occurs because access can only be gained from the exterior of the container [Ref. 40]. Lastly, units who had purchased the system found that the modules were too wide to fit through a standard arms room door [Ref. 51].

4. Special Forces Weapons Transportation Container

The 2nd Battalion, 10th Special Forces Group found their standard weapons racks inadequate for storage of their highly modified M4 Carbines. In order for the weapons to fit within the existing racks, all sights and pointing devices had to first be removed. Additionally, they didn't have any way to securely or easily transport their weapons during deployment. They came up with the Weapons Transportation Container (WTC-1) manufactured by Reese Fabrication of Rockfish, North Carolina. The WTC-1 is an aluminum safe with dimensions of 24" x 24" x 48" that weighs 116 pounds when empty. Although this small safe does not meet this thesis' needs in terms of security, it does have some interesting features. The WTC-1 is nicknamed "A-Team in a box" since it holds the entire weapons complement of a Special Forces A-Team: 12 M-4 carbines, 2 M-24 sniper rifles, and 12 M-9 pistols, as well as the teams night vision goggles, radios, and

various other small equipment items. The WTC-1's internal weapon mounts are "bolt on" to provide ease of modification to accommodate a wider variety of weapons if required. Additionally, the safe mounts removable wheels and a retractable handle for ease of transportation. The WTC-1 costs an average of about $2,000 per unit [Ref. 4 & 52].

Figure 8. WTC-1 Special Forces Weapons Transportation Container [From Ref. 52]

5. Automated Movement Tracking Systems

It is certainly a goal of every logistician to have complete visibility of all assets in the supply chain. So common is this goal that a variety of Automatic Identification Technologies (AIT) (bar codes, optical memory cards, radio frequency identification tags, satellite tracking, etc.) have been used in a variety of different systems at various levels of command in all the Services. The Army's most innovative and cutting edge AIT program is called the Movement Tracking System (MTS), which will provide near-real-time data for in-transit visibility and velocity management of logistics and other Army combat support assets anywhere from the sustaining base to the theater of operations. All supplies will move rapidly from the source, under positive control, through a distribution system, bypassing routine warehouse/storage functions, to the

combatant [Ref. 53]. This system will be physically installed on transportation assets rather than cargo containers; however, cargo assets can have radio frequency ID tags that will communicate with the satellite tracking system on the prime mover to provide true 100% in-transit visibility of the cargo.

Figure 9. Radio Frequency Tag and Handheld Reader [From Ref. 53]

6. Sensitive Item Marking System

Another AIT of interest would be the Sensitive Item Marking System. This is a recent initiative by the Army's Logistics Integration Agency to create an automated arms room with commercial-off-the-shelf components. The system is made up of an individual soldier's common access card, a handheld computer, and micro contact memory buttons affixed to the inventory items. By simply touching the soldier's smart card with the handheld computer's wand and subsequently touching the memory button, the item is recorded as issued. Receipt simply works in reverse. Additionally, time-consuming serial number inventories can be a thing of the past, as the armorer only has to touch each weapon with the wand to achieve accountability of the item [Ref. 54].

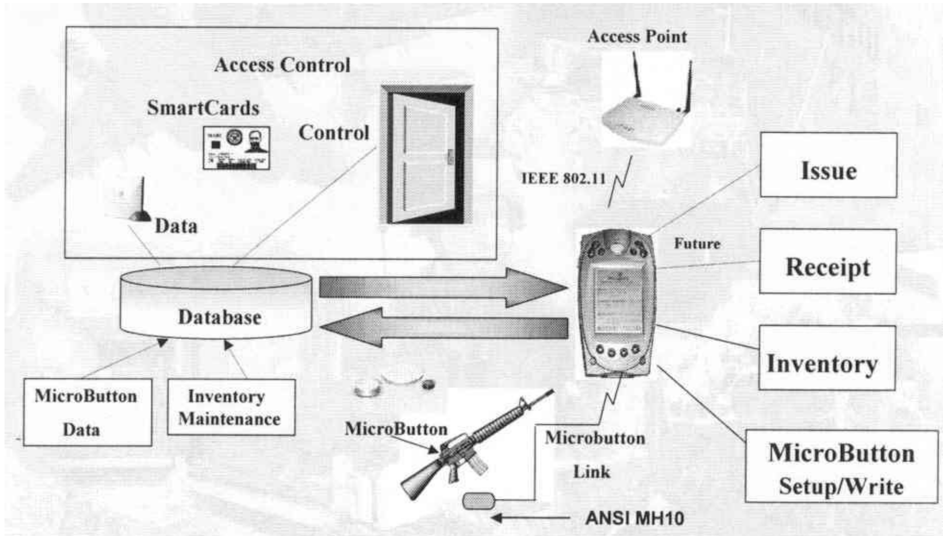

Figure 10. Sensitive Item Marking System [From Ref. 54]

7. Hydraulic Lift Casters

A company named Tandemloc, Inc. of Havelock, North Carolina, has a unique product called Hydraulic Lift Caster (HLC). These casters fit on the twist connection on each corner of the ISO container and enable two people to lift a 70,000-pound container 13.5 inches by hand in only a few minutes. Once installed The HLC can be used to move the container up to 15 mph over paved roads. This device has great potential for short-range movement of containers when MHE or transportation is inadequate or unavailable. The HLC unit price is $33,000 [Ref. 55].

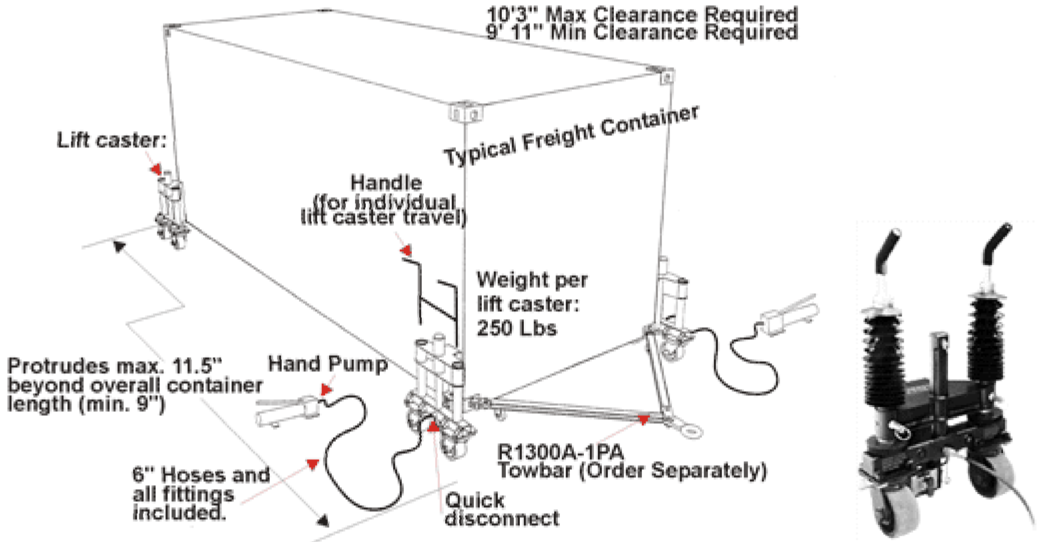

Figure 11. Hydraulic Lift Casters and Tow bar [From Ref. 55]

IV. ANALYSIS

This chapter is a tailored systems engineering analysis. Requirements and functions are analyzed and then synthesized into what the researcher believes to be the most effective and suitable secure storage system design. This design is then analyzed to ensure it meets all required functions and satisfies the major system requirements.

A. REQUIREMENTS ANALYSIS

In Chapter III the user developed multiple requirements; however, exploring existing systems, regulations, facilities, and environments merged additional requirements. Requirements Analysis is used to identify the important tasks that must be performed by the system. This was done using a tailored analysis from the Institute of Electrical and Electronics Engineers (IEEE) P1220 Requirements Analysis' 15 Task Areas. Measures of Effectiveness (MOEs), Measures of Performance (MOPs), constraints, functional requirements, interfaces, and operational scenarios where all considered. Table 3 is the result of this analysis and is presented in a performance parameter format common to Operational Requirements Documents (ORD). A "threshold" represents the minimum standard to which the system must perform, while "objective" represents the desired standard. Systems meeting all threshold standards upon the completion of test and evaluation are typically designated as both operationally effective and operationally suitable.

This list seeks to capture the major requirements within the limited scope of this thesis research. Although lesser requirements do exist, and will ultimately influence the system design, these major performance parameters account for the majority of system design considerations.

Major Performance Parameters	Threshold (T) and Objective (O)
Security	Provide a minimum of 15 minutes of protection against a multi-level tool attack in garrison, during deployment, and upon deployment (T). Meet minimum security regulations for unguarded operation in garrison and upon deployment (T).
Loading	Lift and load system components with 5-ton FMTV material handling crane, or lift and load entire system with 10K forklift (T). Lift and load entire system with 5-ton FMTV material handling crane, or lift and load entire system with 6K forklift (O). Require minimal blocking and/or bracing preparation (T). Require no blocking and/or bracing preparation (O).
Transportation Compatibility	Deploy strategically by sea, rail, highway, and air to include all current USAF transport aircraft, C-130 and above (T). Ensure containers are ANSI/ISO compatible in terms of fittings, features, and dimensions, or ensure system is able to fit within an ISO container (T). Transport by 5-ton FMTV truck (T). Transport by PLS and/or LHS trucks (O).
Storage Space Reduction	Reduce cubic storage space of arms, sensitive items, and valued non-sensitive items stored within existing company arms room by 30% (T), 50% (O). Require no new MILCON for secure facilities for 10 years (O).
Storage Flexibility	Store 95% of all current sensitive items and valued non-sensitive items within storage system (T). Reconfigure internal equipment holding devices (e.g. racks and compartments) within storage space easily and economically to accommodate new or modified sensitive items (T).
Automation	Improve equipment issue, receipt, and inventory processes by 50% (T), 75% (O). Provide automatic identification of system and system contents at debarkation site (T).
Environment	Operate system in all environmental and weather conditions (T).

Table 5. Performance Parameters

B. FUNCTIONAL ANALYSIS

The purpose of Functional Analysis is to transform the functional, performance, interface and other requirements identified in the requirements analysis into a logical and understandable description of system functions that can assist with the design synthesis. By arranging functions in logical sequences, decomposing higher-level functions into lower-level functions, and allocating performance from higher to lower-level functions the researcher can better determine what the system must do, how well, and what constraints might limit the design [Ref. 56]. The following is a basic Functional Flow Block Diagram for the secure storage system decomposed to the second level.

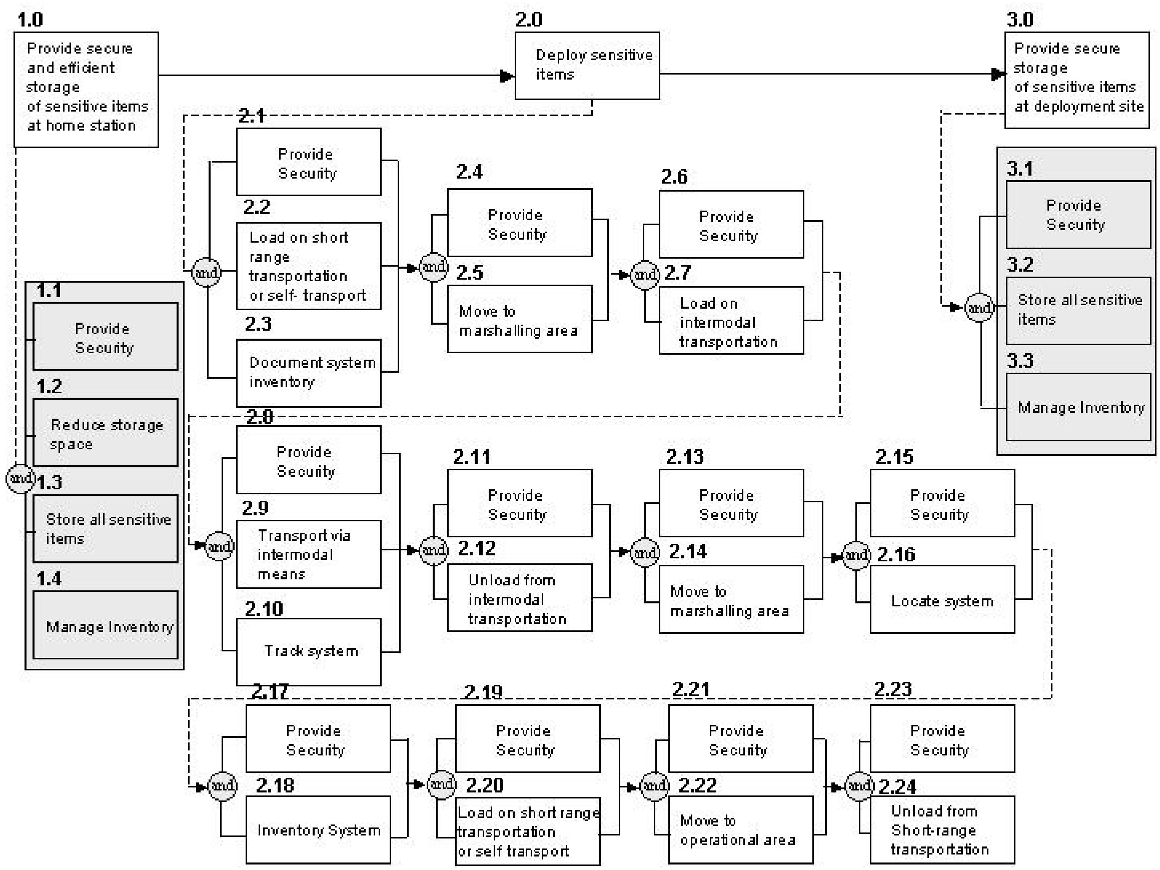

Figure 12. Functional Flow Block Diagram

C. BEST SECURE STORAGE SYSTEM DESIGN SYNTHESIS

After careful consideration of the available data the following system design will best meet the requirements for an Army Secure Storage System. The system will be based upon two major elements: a TRICON type intermodal container and four, multi-configurable, Class 5-level security modules to be stored within the TRICON container during deployment.

1. The TRICON Container

The TRICON Container is a fully ANSI/ISO certified type intermodal container, which has already been purchased in limited quantities by the U.S. Army. It is an extremely flexible design in that three TRICONs can easily be configured into a standard 20-foot equivalent unit. When adjoined, these three containers essentially have the functional characteristics of a side-opening 20-foot container. This side-opening feature greatly increases the interior accessibility of the container, as access doors are available along its full length. This is in contrast to most standard commercial containers that only open on one or both ends.

The preferred design will have one major change over the standard TRICON: it will have an access door on each side, and these doors will be more robust and secure than current models. Currently, standard ISO containers have external locking bars on each door that can be padlocked when the locking bars are in their fully closed positions. To ensure greater security than this external locking arrangement, the container door must have a locking system internal to the door or the surrounding frame. For even greater security, the doors should have unexposed hinges, as external hinges are much easier to breach. The padlocks used in the locking system should be contained within recessed pockets in the door or frame to protect the lock's shackle from bolt cutters or saws. By containing all locking and hinging mechanisms within the interior of the door or frame, the most common methods of invasion: cutting, sawing, and blunt force, are largely eliminated.

An additional modification will consist of a locking interface installed on the floor of the TRICON to firmly secure the security modules to the container. This interface will

prevent modules from shifting during transport and restrict the unwanted removal of the modules by unauthorized or threat personnel.

Each TRICON will have a series of small access panels on each side of the container to enable several containers to be connected together via small ducts to share a variety of functions such as power, security system sensors, HVAC, and dehumidification systems. All such systems that cannot fit within the limited space around the security modules will be mounted externally or configured to fit as a drawer insert into a security module. By connecting multiple containers together to share such environmental and security systems, great monetary and space savings can be achieved.

TRICON containers can either be stored at unit level or at installation level when not being used for secure storage.

DIMENSIONS (inches)		Military TRICON
Internal	Length Width Height	70” 90.5” 86.5”
External	Length Width Height	77.5” 96” 96”
Door	Width Height	71.5” 84.4”
Tare Weight		2,560 lbs
Payload Weight		12,340 lbs

Table 6. TRICON Characteristics [From Ref. 57]

2. The Security Module

The security module is the heart of the entire secure storage system. The security module will be used within the company arms room as a replacement for all current weapons and sensitive item storage racks and cabinets. Upon deployment the security module will be manually moved out of the unit arms room and four of these modules will be stored within the TRICON container. The modular cabinets are loaded back to back into the container, and consume almost its entire interior space, thereby maximizing its

cargo utility. When installed in the side-opening container, these modules face outwards on both sides, thereby allowing full access to the entire contents of the container.

A critical constraint for the module is that it must easily fit through the 34-inch by 83-inch interior doorframe of an arms room [Ref. 58]. It must also have a base that can accommodate forklift tines or pallet dolly roller tines as well. Overall Module dimensions of 33 inches (width) by 80 inches (height) by 45 inches (depth) would allow for sufficient side clearance while allowing a pallet dolly to lift the module and roll it through doorways with sufficient overhead clearance. Additionally, with a depth of 45 inches, a full-length M-16A2 (39") or OICW (33") could be stored within the module horizontally, making weapons storage more efficient.

The security module is similar to a current GSA-approved secure (1.75-inch thick steel walled) filing cabinet in that it is built to safe-like standards and has drawers. The primary difference - and the key to its flexibility - is the ability to accommodate a variety of drawers of different depths within the same module. With receptacles for a drawer mounted every four inches, an almost limitless combination of different drawer depths will be possible. Each drawer will have customizable internal partitions to easily organize the items stored within. These partitions will also prevent the contents from shifting within the drawer.

Drawers used for weapons storage will typically hold the weapons horizontally. Each weapons drawer will be fitted with a commercial-grade, foam-type, protective insert that can be easily factory molded to fit any combination or configuration of weapon systems. Of course these cheap molded inserts can be used to hold and protect other secure items where standard drawer partitions may be inappropriate.

Each drawer will have a relatively thin, metal, lockable top cover that will essentially make each drawer secure unto itself. This is the equivalent of having separately-locked arms racks.

Instead of armoring the front of the drawers as in the current secure filing cabinet, a swinging armored door will fully enclose the front of the storage drawers. A high-security lock, with a protected hasp to prevent the cutting of its padlock's shackle, will secure this door to complete the security envelope. This door will have interior rubber

seals to protect the drawers from dust and moisture; however the door will include a closeable vent to be opened during extremely humid environments when a dehumidifier is operating within the system.

3. Other System Characteristics

An Intruder Detection System (IDS) will have an installation space reserved above the security modules in the interior of the TRICON container. Since the containers can be connected, and one IDS can support several TRICONs, it will be up to the unit to decide how many IDS systems are required to provide adequate security.

Each container will have an internal lighting system installed that is both white and red light capable. There will be an automatic light sensor to ensure only red lights are turned on during periods of darkness.

Each container will have some type of retractable, overhead, protective awning or panel that can be pulled out to protect the user and the contents of the drawers from precipitation when the container and the module drawers are open.

Each company will be issued a hand-operated pallet dolly as a system component. This dolly will provide an inexpensive and efficient means of transporting modules in and around the company area, and loading them into a ground mounted TRICON. The pallet dolly must abide by the width constraints imposed by the arms room door.

As part of the system, each installation will maintain from four to six hydraulic lift caster sets with tow bar. Since combat arms and combat support battalions have so little transportation and MHE assets, such a system component will provide an inexpensive solution for this serious shortcoming. While the support battalions will focus on preparing the installation’s main effort for deployment, units selected as lower deployment priorities could be issued the HCLs to get an early start on moving their containerized equipment. With the caster set, units can manage their own TRICONS into 20-foot equivalent units and then tow them to their division’s railhead or truck ramp for outload with little or no assistance from the DISCOM.

To further facilitate rapid outload, part of system fielding will include the addition of two RTCHs to each division-size installation. This addition to the table of

organization and equipment will ensure all Army divisions and separate brigades have a robust and efficient container handling capability that will be necessary to support the increase in container operations that the secure storage system will require.

The final system design feature is an AIT system to assist with managing inventories and maintenance actions. Such a system should maximize commercial-off-the-shelf (COTS) information technology components and be fully portable for use in garrison or when deployed. As part of the complete AIT system, each storage system will be able to accommodate an RF tag, and each battalion will have an RF reading unit. The unit level inventory management system will export the internal inventory of the system to the RF tag. This tag will then work in conjunction with satellite tracking systems mounted on transportation assets to monitor the container during deployment. The RF tag will then make it easy to locate the container upon debarkation, and to provide a list of its contents when queried.

D. DESIGN ANALYSIS

1. Security

Since the TRICON container does not meet the structural standards of a Category II arms storage room or building, its interior modules must meet GSA approved Class 5 security container standards. If designed as above, the security modules should meet these security standards and regulations set forth in Chapter 4 of AR 190-11 Physical Security of Arms, Ammunition, and Explosives and Federal Specification AA-V-2737. However, since the design of the security modules differ somewhat from that of a GSA approved secure filing cabinet, the design will ultimately have to be approved by the GSA. With the level of security these modules shall supply, as long as the storage system is equipped with an IDS system it should be able to be left unattended while only being checked by a security patrol once every 8 hours.

Although the security modules will actually exceed security requirements as they sit within existing arms rooms, one major advantage of the system is that the modules can be used in non-secure structures or rooms as well. If space within the arms room is exhausted, these modules can be placed into a non-secure structure or room (such as the supply room) and, as long as an IDS is installed within the space, they can be left there

unattended. Based on the commander's risk assessment, if the modules do not contain arms, but rather only other sensitive items and non-sensitive valued items, it may be quite possible to store such modules outside the arms room and not even require an IDS. The ability of this mobile module to expand the secure characteristics of any existing structure makes it a great alternative to any military construction option.

There is one security issue that cannot be addressed by the system. During rail and truck transport intermodal containers carrying bulk arms shipments are required to be arranged door-to door on their transports so as to have their doors physically blocked to prevent them being opened in transit. Since the system's containers have dual doors, arranging them door-to-door still leaves exposed doors unless the transport platform comes equipped with fore and aft bulkheads. However, since the design of the secure storage system's doors is significantly more secure than those of current ISO containers, it is reasonable to believe that this requirement could be waived.

2. Loading

One of the primary reasons for selecting the TRICON container is due to its low tare weight and the general ability to "manhandle" it due to its relatively small size. These are both attributes that make it much easier for owning units to more easily lift and position it onto some mode of transportation. Although the Forward Support Battalion has MHE assets that it will likely provide to its supported battalions, the pessimistic system designer would not count on such external support. By ensuring that at least the system's components can be individually lifted onto an organic 5-ton truck with its material handling crane and then assembled for movement, the unit is in much greater control of its destiny in transporting its secure items. Additionally, when the Support Battalion does indeed provide its MHE assets to its supported units, the TRICON's low tare weight leaves a greater opportunity to exploit the large numbers of 6K forklifts within the DISCOM – its most plentiful MHE asset [Ref. 44].

Another aspect of loading the container is preparing its contents from shifting during transport by blocking and bracing the contents. Blocking and bracing is typically accomplished by using wood or other materials to make temporary internal walls within a container to prevent the contents from shifting. Since the base of the modules lock into

the floor of the container in this system, there is no need for traditional blocking and bracing. .

3. Transportation Compatibility

The system's greatest transportability strength is that it is compatible with all commercial and U.S. military intermodal systems. However, since the selected system design is not immediately ready for air deployment, some analysis is needed to decide between this small ISO container and the air transportable ISU-type container. With the Army's new focus on rapidly deploying a wider range of forces via USAF aircraft, and with its large number of forward-based forces, the ISU container would seem to be a better platform. However, a sustained air deployment is unrealistic as the numbers of aircraft are inadequate for the task. The bulk of Army equipment will deploy by truck and rail from their home installations and then be transferred to Navy and commercial shipping assets to complete their journey overseas.

Another deciding factor is that an ISU equipped unit faces difficult choices when it does not deploy by air. Since ISU containers are not intermodal they must be either loaded onto intermodal flatracks or inside ISO containers if deployment by sea is decided upon. Since units are unlikely to maintain these intermodal assets on hand, the units will have to wait for these containers to be rented and shipped to their installations. And as the data in Chapter III indicates, circumstances can dictate the availability and adequacy of any given type of intermodal container. By procuring an ISO container such as the TRICON as the deployment platform in the first place, there is no delay in preparing for deployment as all the container assets are already in place.

Of course the opposite situation could occur as well: where the TRICON equipped unit may have to deploy by air. First, the TRICON fits nicely upon a 463L pallet. Second, 463L pallets are much more likely to be maintained by an installation since they are required for military air transport and are unavailable commercially. Additionally, these pallets are much more easily stored than ISO containers since they stack like plywood. Even if they are not stored on the installation, the Air Force can provide them to make up for shortfalls.

Another plus for transportability is that three TRICON containers can be connected to form a 20-foot equivalent unit. Thus, larger MHE assets such as PLS, LHS, and the RTCH, which routinely and easily move 20-foot units, can be taken advantage of to rapidly move multiple units where needed.

4. Storage Space Reduction

The secure storage system has three major design features that create efficiencies in storage space and usage time. First, the secure modules almost completely fill the interior of the system. This design maximizes the internal space of the container, as a human does not need to walk inside the container to gain access to its contents. Most ad-hoc, and even professionally fabricated, secure storage designs use the concept of a portable room surrounded with interior weapons racks. To gain access to the weapons, a person must physically walk into the room and select a weapon from one of the racks. By keeping the space open that is required for a human to move about within the room, up to one third or more of the available interior storage space is wasted.

Second, the experiences of the aforementioned BOH Environmental, LLC, whose modular FPU had the greatest influence on this storage system design, reveals much about the efficiency of an organized, modular system. Space savings of greater than fifty percent are almost always the case when a user organizes his/her equipment using modular storage units [Ref. 59]. By taking what is already in existing arms rooms, and reducing the storage footprint by fifty percent, one of the most pressing problems presented in this thesis: arms room overcrowding, is solved.

Third, the TRICON's interior length of 70 inches, height of 86.5 inches, and a depth of 90.5 inches, ensures that the four internal secure modules, measuring 33x80x45 inches, minimize wasted space within the container while maximizing secure storage space. This fact alone makes the ISU-type container a poorer choice for a modular platform since the constraints on the module's size results in much wasted space within the larger ISU. Additionally, since only two ISU containers can fit within a 20-foot ISO container (assuming 83-inch or shorter ISU containers are used), this means only eight security modules can be transported in the same deck space as three adjoined TRICONs - which can transport twelve modules. Of course, the security modules will still easily

fit within an ISU, and a module-locking interface can certainly be developed for the ISU if this capability is desired.

5. Storage Flexibility

The secure module explanation section found above describes the flexible design features of the module drawers. These drawers are truly the key to the flexibility of the security module as they can conform themselves to almost any stored item and are independent of any locking mechanism that might intrude into the drawer space.

One of the greatest benefits of the security module's drawer design is that it enables program managers and contractors to have a firm planning factor when determining the storage needs of their sensitive and valued non-sensitive items. For example, the product manager for a new night vision goggle would know exactly what size drawer will fit his goggles, and how many of these drawers will be needed to accommodate the full contracted amount. With this knowledge he can better judge his program support costs. In another case, a laser site manufacturer who produces a site that mounts on the side of an M-4 carbine could assess the impacts of this modification on the space within one of the standard-size storage drawers. He could then subcontract for a cheap foam drawer insert to accommodate the sites as they sit astride multiple M-4s in the drawer. This new insert would be part of the contractors total support package for his site.

6. Automation

Inventory management of weapons and other sensitive items is pure drudgery for those executing the task. By automating the processes involved, significant time savings can be achieved. This will allow the armorer to concentrate on other pressing tasks such as maintenance. Such automated inventory management systems are likely to leave the physical security inspectors a bit concerned, but the technologies involved have been proven by many commercial applications over time and should serve the military well.

Radio frequency tags are the solution to the Desert Storm quandary where mountains of stored equipment completely lost their visibility to the logistics managers. These tags, working in conjunction with worldwide satellite tracking systems, will finally

bring total asset visibility to the supply chain. As such it is essential they be included as part of each system.

7. Environment

The secure storage system, when closed, is almost totally resistant to all environmental conditions. However, when it is open and being utilized, its drawers are largely exposed to the elements when they are withdrawn from their modules. This being the case, a retractable awning must be an element of the design. A rigid panel could be suspended from the top of the interior of the container and be withdrawn when needed, or a retractable fabric awning could be mounted externally to the container. Regardless of which awning design proves to be optimal, the addition of such a protective device is a must.

8. Cost

Since no hard data exists on this system design, cost can be determined only on a rough order of magnitude. This thesis does not seek to use system cost as a design consideration; however, the consideration of cost will be unavoidable in an actual acquisition program. This being the case, the following calculations were derived for comparative purposes to get a feel for how the system might compare to commercial alternatives.

A TRICON intermodal container costs $2,789 at an estimated division level quantity of 210 units [Ref. 6]. Expect a price increase of 30% to incorporate the newly designed doors and interior features such as lights and power connections. This brings the price to $3,626. Since the security module is a unique design, no cost data is available; however, the FPU module is quite similar. Even so, their $13,793 price per module seems a bit excessive. The price for a quantity buy in a competitive environment would likely fall between ½ and ¾ of this price, or $8,620. Consequently, the final price for a complete secure storage system would be near $38,106 per unit. The cost for a 20-foot equivalent unit (3 systems) would add to $114,318 – about $45,000 less than the 20-foot FPU system - but with 2 more storage modules than the FPU. The total cost for a division-size buy would come to $8,002,260 just for the container system. This does not include system level costs such as pallet dollies, hydraulic casters, and the two RTCHs.

E. TRACEABILITY MATRICES

The following matrices are a graphic tool to demonstrate that design synthesis has resulted in a physical architecture that meets the requirements of the seven major performance parameters. This measure completes the Verification Loop of the SEP.

PHYSICAL DESIGN ELEMENTS	MAJOR PERFORMANCE PARAMETERS						
	Security	Loading	Transportation compatibility/ improvement	Storage Space Reduction	Storage Flexibility	Automation	Environment
Steel TRICON Container	X	X	X		X		X
Improved TRICON doors	X						
High security modules (33"x80"x45")	X			X	X		
Floor locking mechanism for modules	X	X					
Connecting utility ducts	X					X	X
Multiple module drawer configurations				X	X		
Reconfigurable module drawer partitions and inserts				X	X		
Individually locking module drawers	X						
Intruder detection system	X						
Internal power wiring and light system	X					X	X
Dehumidifier							X
Protective awning							X
Automated inventory management system	X					X	
RF tag and reading system	X					X	
Loaded TRICON and module system < 10K pounds		X	X				

Table 7. Physical Architecture Design Traceability Matrix

SYSTEM DESIGN ELEMENTS	MAJOR PERFORMANCE PARAMETERS						
	Security	Loading	Transportation compatibility/ improvement	Storage Space Reduction	Storage Flexibility	Automation	Environment
Module hand dolly		**X**	**X**				
Hydraulic lift caster set			**X**				
2 RTCHs per installation		**X**	**X**				

Table 8. System Level Architecture Traceability Matrix

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V. CONCLUSIONS AND RECOMMENDATIONS

In this chapter the primary and subsidiary research questions are examined and conclusions are presented. In addition, recommendations for future actions are offered.

A. PRIMARY RESEARCH QUESTION

What is a system design that can provide the Army with security, protected storage, availability, and accountability of sensitive and valued non-sensitive items and equipment in garrison, during strategic deployment, and when deployed for training and operations?

Based on this tailored systems engineering analysis it is apparent that a design that is both modular and intermodal best satisfies the present and future requirements of a U.S. Army secure storage system. However, this primary research question is more completely addressed by the responses to the four subsidiary research questions. The conclusions to these research questions and the accompanying recommendations are presented below.

B. FIRST SUBSIDIARY QUESTION

What features and performance levels will the system's users require?

1. Conclusions

Regardless of the reasonable and studied visions of system designers, the user provides critical insight into the features and performance levels of the system, and thus must be included in the system design process from its earliest inception. Even the rudimentary nature of the input gathered from "users" for this research, radically influenced its design. For example, early studies conducted by the Army Corps of Engineers examining the secure storage issue depicted an installation-level centralized storage annex. The users flatly rejected this centralized design concept in favor of utilizing existing facilities. These existing facilities were important to the user as they provide the commander with the desired amount of control and administration over mission critical sensitive items. This decision in turn mandated that the design optimize the storage space within the existing arms rooms to allow for their continued use. Super-organized security modules were the result of this need. Subsequently, the constraints of

the existing arms rooms (the doors) restricted the dimensions of the security modules, which, in turn, influenced the container type selected to house the entire system. Ultimately, the users provided input that resulted in reconfigurable storage containers, greater transportation compatibility, manual transportation methods (hand dollies), HVAC access capability, electrical wiring and lighting recommendations, and an end to blocking and bracing procedures

2. Recommendations

Future studies and design analyses should include input from a robust sample of Army personnel (and perhaps other DoD personnel as well) from the widest spectrum of expected users. Failure to do so may result in a system that is operationally effective, but not necessarily operationally suitable.

C. SECOND SUBSIDIARY QUESTION

What are the major security and transportation requirements and constraints in developing a mobile secure storage system for a fixed facility, and for its deployment into an area of operations?

1. Conclusions

Perhaps the greatest threat to this design was not meeting established security requirements as set forth in Army physical security regulations. After all, if a security system cannot be made adequately secure what is the point? However, the system can indeed meet these requirements by utilizing GSA approved Class 5 Security containers stored within a steel intermodal container. However, this robust steel construction is likely to push the maximum system weight of 10,000 pounds. A system weight beyond this ceiling would prevent it from being transported by the 5-ton tactical truck.

Just as significant was the requirement that this be a mobile secure storage system, capable of being deployed into an area of operations using existing transportation and material handling systems. This requirement presented the greatest challenge and had the most profound impact on its overall design. Only an intermodal container can house a bulky system that potentially could be transported via highway, rail, water, or air. Additionally, only a small intermodal container (the TRICON) can be lifted and hauled by the limited material handling and transportation systems found in combat arms

companies and battalions. By using a small intermodal container that can be joined together with others to form a standard-size, 20-foot, intermodal container, the largest range of Army transportation and material handling assets can be utilized. Furthermore, this standard configuration takes advantage of the full benefits of commercial transportation assets and processes. This standard configuration is a significant feature since commercial shipping provides a large percentage of the Army's power projection capability. Although military airlift systems are not optimized by using a system based on an intermodal container, the TRICON is completely compatible if configured properly on an Air Force 463L pallet prior to flight.

2. Recommendations

Although the all steel construction of this system ensures it meets the security requirements, it results in significant weight. Lighter weight materials (specifically, aluminum security modules) are recommended to improve the transportability of the system. Consequently, any material changes to major components need to be extensively tested and evaluated to determine system effectiveness in the new configuration. Subsequently, security regulations may need to be revised to allow for these new material changes if they prove to be effective.

The majority of Army containerization initiatives have focused on artillery ammunition resupply, pre configuration of division Authorized Stockage Lists (ASL), and general force sustainment efforts at the Corps and Theater level. Although this research only deals with containerization of a secure storage system, it is recommended that logistics experts and force designers closely examine the utility of small unit containerization as a method to reduce their logistical footprint and to improve these unit's deployment response time.

D. THIRD SUBSIDIARY QUESTION

What commercial equipment and technologies are available which might be suitable for inclusion as part of a mobile secure storage system?

1. Conclusions

There is no part of the proposed system design that cannot be easily supplied as a commercial-off-the-shelf (COTS) item. In fact, the author was surprised at the number of

intermodal container manufacturers, as well as the large number of companies that specialize in the custom modification of intermodal containers. Additionally, manufacturers of custom safes for home use have become ubiquitous across the United States. Lastly, the number of firms utilizing GPS and RF technology, used to assist commercial trucking and shipping companies to achieve total supply chain visibility, have exploded over the past decade. Certainly, within these three industries competition abounds. A secure storage design using such system components should benefit from this environment in terms of system quality and price.

2. Recommendations

Use a COTS-based acquisition strategy. Utilize the competitive environment to maximize system quality and price, and to consequently reduce overall life cycle costs. Additionally, it is recommended that the system be purchased in quantity to net the lowest overall system cost.

E. FOURTH SUBSIDIARY QUESTION

What are the benefits of such a secure system design for the Army and DoD?

1. Conclusions

The following are benefits of this secure storage design:

- Meets all Army physical security regulations for remote deployment
- Can be loaded on and transported by the Army's common 5-ton truck, and be handled by most material handling equipment common to the Division Support Command
- Requires no blocking or bracing preparation
- Configures into a standard 20-foot ISO container equivalent to increase its flexibility in both Army and commercial shipping environments
- Deploys strategically by sea, rail, highway, and air (ISO and 463L compatible)
- Reduces cubic storage space within existing facilities

- Stores an extremely wide variety of sensitive items due to its reconfigurable internal racks and compartments
- Reduces the need to acquire bulky, hard-sided protective cases for sensitive and valued non-sensitive items
- Improves equipment issue, receipt, and inventory processes through information technology automation
- Provides increased visibility of its contents throughout its deployment, and automatically identifies itself for easy location through the use of radio frequency technology
- Operates in all weather conditions and environments
- Provides for "on-hand" container systems ready to facilitate rapid deployment, instead of waiting on leased assets to arrive for outload
- Provides a standard, systemic storage solution to ease the storage planning burdens of program managers when fielding new sensitive or valued non-sensitive items

2. Recommendations

The United States Army should consider such a secure storage system for an acquisition program; however, a thorough cost-benefit analysis should be conducted to confirm the feasibility of such a program. Additionally, the modular containerized concept should be considered for expansion beyond secure storage. Lighter, less expensive, non-secure modules could replace the secure modules and retain all the system benefits except for the level of security. Such a system could be instrumental in improving storage efficiency and greatly increasing the tempo of deployments throughout the Army.

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